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AN ULTRASONIC AID FOR THE BLIND

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AN ULTRASONIC AID FOR THE BLIND

by

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ABSTRACT

In an age of rapidly advancing electronics, and subminiaturization, the possibility of providing convenient electronic aids to the physically handicapped is becoming a reality. Devices for the deaf have reached a degree of sophistication not thought possible several years ago. The blind, however, have not reaped the benefits of modern electronics technology to the degree that the deaf have. This thesis describes the work accomplished in designing and testing an ultrasonic aid for the blind. This device provides range and bearing information of nearby objects by means of tactile stimulation, and would provide a useful adjunct to the walking cane.

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TABLE OF CONTENTS

Chapter — Page

I. INTRODUCTION 5
Historical Background 5
The Problem 9
II. DESIGN 13
Criteria 13
Approach to Design 17
III. IMPLEMENTATION 19
Receiver 19
Transmitter 24
Timing Circuits 28
Readout 31
IV. RESULTS 36
Testing 36
Feasibility 39
V RECOMMENDATIONS AND CONCLUSIONS 41
Conclusions 41
Recommendations 43
BIBLIOGRAPHY 44
APPENDIX 45

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CHAPTER I

INTRODUCTION

There have been many attempts to solve the problem of blind guidance in the past. The devices which were developed ranged from the very complex to the extremely simple. These devices differed in two main respects; one - in the manner in which the basic environment information was obtained, and two - the means by which this information was transmitted to the blind person. These two categories will be covered separately, introducing the relative merits of each system.

As a guide for systems development the various aspects of environment sensing will be delineated.

I. HISTORICAL BACKGROUND

Environment Sensing Devices

Environment sensors have generally been active or passive and have used the following for detection:

a. audible sound (sonics)

b. ultrasound (ultrasonics)

c. radio frequencies

d. visible light

e. infrared light

f. ultraviolet light

Sonics. Devices employing sonic ranging primarily used audible clicking sound projectors, with detection directly by the ear. These devices required parabolic reflectors and some sort of manual operation. The devices that fall into this category were the first attempts at a solution to the problem. As such, they had many shortcomings. They could not be used in noisy locations, since the ambient noise level

masked the projected sound. The audible output attracted attention and proved to be an annoyance to the user over prolonged periods. The devices gave no indication of step-up or step-down and only crude information in range and bearing. The user required long periods of training in echo recognition. Their advantages were relative simplicity and the maximum use of the natural facilities of the user.

Ultrasonics. Because radar techniques could be employed, ultrasonic devices have received the greatest amount of attention from the engineer. Devices which used ultrasonics were comparatively unaffected by rain, fog, and sunlight and by normal ambient sound conditions. These devices could detect step-ups but not step-downs. The results of tests on these devices indicated that at best they were good for go-no-go obstacle detection. In addition, their efficiency was reduced by specularity, air turbulance and doppler effects. These devices also needed parabolic reflectors to avoid specularity. These needed to be twenty to thirty times the wavelength for good bearing resolution, thus making them impracticable for portable use. Those devices for which information was available generally used magnetostrictive transducers.

Dr. L. Kay has developed an ultrasonic aid in the form of a hand-held device of flashlight size. This device uses a frequency modulated carrier wave in the ultrasonic region. Returned echos are beat against the oscillator and the resulting beat frequency monitored by an earpiece. This device has two ranges, seven, or twenty feet maximum. Bearing information is obtained by aiming the device. Its specifications indicate it can show the presence of objects with good reflectivity at a range of twenty feet and such hazards as a two inch diameter post at ten feet.[1]

[1]L. Kay, Ultrasonic Aid for the Blind, Appendix XVI

Radio Frequencies. Two systems have been developed that use radio frequencies for the detection of environmental changes. Both of these are cane-like devices for the detection of small changes in terrain, i.e: step-up or step-down. One developed by General-Dynamics/Electronics uses the effective capacitance to ground of a small antenna to change the frequency of a 2 Mhz oscillator. The frequency of this oscillator is then beat against another 2 Mhz oscillator, which is calibrated with the cane held at a given height to produce a zero beat. If the distance to the ground remains unchanged, there is zero beat and hence no output. When the cane passes over a change in terrain such as a curb the effective capacitance to ground changes and an audible signal is heard in an earpiece.[2] These devices are limited to a maximum range of a few inches, but are very accurate within that range interval.

Ambient Light. The use of the ambient light present in the environment has received relatively little attention from those working in the field of blind guidance. However, recent work under an Air Force contract has indicated that this might ultimately be the best method of obtaining all of the information needed to solve the specific problems associated with blind guidance.[3] This method proposes "to process natural light in such a manner that its effect will be 'felt' by selected portions of a blind man's skin, perhaps on his fingertips, but preferably on his face."[4] In general the advantages of an ambient light system would be the absence of the requirement to generate a source

[2]Bucher, W.B., Medical Electronics PART IV; Prosthetics - Hearing Aids and Blind Guidance Devices, Electronics, June 1961, pp. 43-49.

[3]Bishop, W.B., Environment Sensing; A New Approach to the Design of an Electronic Aid for the Blind, AFCRL 63-64.

[4]Ibid., pp. 5

signal. In addition, high sensitivity could be achieved with low power consumption. A disadvantage is that patterns on the obstacles could lead to false signals. It also would not be useable at night, without an auxiliary light source.

Infrared, Visible, and Ultraviolet Light. Systems using projected infrared, visible and ultraviolet light have been developed and tested. These devices do not suffer from specularity as do those employing sonics and ultrasonics. It is possible to project very narrow beams, so as to be able to trace the outline of objects. However, their performance suffers from saturation due to sunlight and other ambient light conditions. In addition, rain and fog adversely affect their performance. Adequate environmental information is difficult to obtain and would require complex circuitry to translate it into useful information for the blind person.

The Human-Device Interface

The replacement of the eye function per se is a major engineering feat that could not be accomplished without a complete knowledge of the information rate and method, by which visual information is presented to the brain. Without a direct nerve contact, such as exists in the normal eye, one could not hope to replace the eye-function. One must then be satisfied with supplementing the information received through hearing and feeling, when there is a loss of sight. From an engineering viewpoint, aural information was the easiest to develop. However, those devices which have used aural techniques were objected to by the blind. The amount of information presented by the device did not off-set that lost by the aural interference it caused. Tactile readout has been limited by the development of adequate tactile stimulators. Recent

developments in a direct reading aid for the blind has shown it possible to construct large arrays of transducers using piezoelectric crystals.[5] In addition, it was shown that the amount of power required to produce a tactile sensation increases as the frequency is lowered. It is significant that the power required to drive the stimulator, to go above the threshold of sensitivity within the fifty to two-hundred hertz region, remains in the micro-watt range.

II. THE PROBLEM

Statement of the Problem.

To those of us who see, the ability to move about safely is not a paramount problem. We do not spend a large portion of our time trying to establish three dimensions and in knowing the position of ourselves and the rest of the world within those dimensions. The precise manner in which we establish our position cannot be clearly stated. It depends not only on our ability to see, but upon the ability of the brain to sort the various inputs of information received through seeing, hearing, feeling, muscular movement, etc. By these means one is able to sense his position relative to his environment. Seeing is our most important asset in sensing our environment. By means of sight we are able to measure distance, recognize azimuth and elevation, recognize shape, color and texture. We are also able to recognize both our movement through our environment and movement other than our own.

The blind person is presented with an almost insurmountable problem. He or she must be able to maneuver in an environment that is geared to those with sight. The blind have remarkably been able to do

[5]Linvill, J.G., and Bliss, J.C. A Direct Translation Reading Aid for the Blind. Proceedings of the IEEE. Vol 59, No. 1, Jan.1966, pp. 40-51.

better than the occasionally blindfolded, but only under very rigid conditions. Their environment must not change and they must be given enough time to become accustomed to it. Even the casual rearrangement of a piece of furniture could prove disastrous to the blind person.

Simply stated, the blind person must be able to sense sufficient information about his environment to be able to move about safely. He must be able to do this in various environments and under changing environmental conditions.

Specific Environment Sensing Problems

Before considering a design approach, it was important to review some of the facets of the specific problems that would be encountered by the blind. These problems and the conclusions reached apply equally well to the environment sensing problems encountered by unmanned vehicles.

Obstacle Avoidance. The blind person must be able to determine in which direction obstacles are located and at what distance from himself. The device should indicate in some manner either the presence or non-presence of objects at a distance.

Pitfall Avoidance. The device must be able to indicate the presence of pitfalls and should be able to indicate the size of the pitfall and its associated boundaries. An example of this category would be an open manhole. It would not be necessary for the device to give a continuous indication of the terrain about the blind person, but only whether or not a danger exists in the immediate vicinity of the traveler.

Step-down. This problem is similar to the above in that pitfall boundary location is important. However, the size of the step or the depth of the step is also important, ie: is the downward change in the

terrain of such a nature that the blind person can safely maneuver the step.

Step-up. Again the location of the boundary and its extent is of importance. A large step-up will undoubtedly show as an obstacle, and the indication that a step-up is present is most important when the degree of the step is small and can be managed by a moderate amount of leg movement.

Low Overhead. The sensing device should be capable of indicating the approach and passing of low overheads that will require the blind person to bend or crouch to avoid hitting them.

Vehicle Recognition. The device should be able to distinguish between approaching and departing vehicles and give an indication of their rate of movement. A blind person with adequate hearing will undoubtedly have acquired a good deal of ability in vehicle recognition by aural means, and the device should be able to supplement this aural ability. With this in mind, one should think of a device which will have the ability to observe short ranges or longer ranges at the discretion of the operator.

Object Recognition. The blind person "sees" objects primarily by feeling them and noticing their general shape and texture. In a like manner, the device should be able to give an indication of the shape of the object (if only a two-dimensional one), and perhaps an indication of the texture of the object. The blind person would, by repeated use of the device, be able to recognize patterns and tell what the object was. For instance, one should be able to distinguish where a door exists in a given room environment. He should be able to distinguish the size of detected objects within the tolerances of the equipment.

Navigation Between Known Coordinates. An indication of position, with respect to a fixed coordinate system, is desirable and should be updated by the present surroundings. This problem would require much more precision than one would expect to package into a hand held device and, in addition, would require a greater amount of attention by the blind person.

The problem of blind guidance then, is one of providing suitable environmental information, sufficient to allow increased freedom of movement without sacrificing safety. In addition, a sensing device for blind guidance should be capable of providing additional information, such as object texture, that is not of immediate importance in guidance.

The investigators chose to design a system that would be an application of radar techniques to ultrasonics.

CHAPTER II

DESIGN

The problem was delineated as the design and testing of a radar system for the blind. This system was to utilize ultrasonic techniques for detection, and a tactile interface for transfer of data to the blind person. Immediate considerations included conventional radar principles. It was apparent that all range and bearing measurement techniques were applicable, regardless of the eventual system configuration.

I. CRITERIA

The design problem involved the following considerations:

a. active versus passive
b. frequency of operation
c. type of transducer
d. type of readout, the human-device interface
e. range requirements
f. size of equipment
g. power requirements
h. cost of the device.

To a great degree all of these requirements are interlocked, and in as much as the device should ultimately be used for blind guidance, some requirements must immediately be satisfied, ie: size must be limited to hand held portability, power must be furnished by battery, and readout must make use of tactile sensation. Size and power limitations immediately imply the use of solid state techniques. In this manner, power consumption may be made minimal and portability maximized. Specifically, the use of integrated circuitry should be used where ever possible. Integrated circuits are generally limited in application, and high in cost.

Transistors were then the natural choice, with integrated circuitry to be used when and where available.

Passive Circuitry

Past investigation and physical reasoning indicate that acoustical waves are produced everywhere, as are heat, light, and radio frequency waves. Thus, the ambient level of any of these waves might be used with proper sensing to give guidance information. Passive systems were generally eliminated from consideration, due to the many inconsistancies and variables noted by previous workers in this field.[1]

Active Circuitry

Active systems include the same spectrum considerations as do passive, ie: acoustical, radio frequency, heat and light. The dominate problem encountered in using active systems is the method of transmission of energy and the power required to do so. Given sufficient power and methods of producing such waves, the next problem is processing the returned information. Radio frequency and light waves travel at such high speeds that measurement techniques become ambiguous at short ranges (for phase comparison techniques). Heat waves suffer great attenuation and require a hot source. Acoustical waves have a slower propogation velocity, and are a logical choice for short range echoing. By using such waves, conventional radar techniques can be used to a large extent. In addition, suitable transducers were available for production of ultrasonic waves.

Frequency of Operation

Production of acoustical waves is possible throughout the spectrum of radio frequency waves. In considering the range of acoustical waves

[1]Wm. E. Buchor, Medical Electronics Part IV, Electronics (June 1961). pp. 46-47.

to be investigated, the first consideration is propogation and attenuation characteristics in air as a function of frequency. Attenuation in dry air varies from about 0.09 db per meter at 20 Khz, to about 60 db per meter at 400 Khz.[2] It became apparent that any consideration of frequencies above 1 Mhz was useless. Furthermore, frequencies below 20 Khz are generally within the range of audibility, and since a blind person uses these frequencies for conversation as well as some simple echoing, these frequencies were ruled out. Serious concentration was then focused in the range of 20 Khz. to 1 Mhz. Here the choice of the lower frequencies for less attenuation and availability of commercial transducers at 40 Khz made the choice obvious.

Transducers

Commercially produced piezoelectric transducers operating at 23 Khz and at 40 Khz were readily available. Both frequencies give similar propogation characteristics. The transducers operating at 40 Khz were chosen. This choice was determined by the shorter wavelength, hence smaller transducer size, and the fact that 40 Khz was out of the range of animals and insects.[3] Investigation of magnetostrictive, electromagnetic, and capacitive transducers available showed the piezoelectric superior for this use.

Readout

Either aural or tactile interface readout could be accomplished. Aural was eliminated in favor of tactile, due to the already predominate use of aural channels for communications and "navigation" as

[2]L.E. Kinsler and A.R. Frey, Fundamentals of Acoustics (New York: John Wiley & Sons, Inc., 1962), pp. 232.

[3]Pye, J.D. and Flynn, "Equipment for Detecting Animal Ultrasound". Ultrasonics, Vol. 2, Jan-March 1964, pp. 23-28.

previously discussed. The tactile readout was chosen to be of a digital nature, such that five range increments would be provided, corresponding to the five digits of the hand. The presence of a target within a range interval would produce a tactile stimulation on the appropriate digit. Further discrimination within a range interval could be accomplished by varying the frequency of stimulation. Investigation of the variable frequency technique was carried out, but breakdown within each gated range interval was abandoned in favor of on-off information, due to the complexity and expense of the former system Furthermore, investigation of echo-ranging on the oscilloscope indicated that the most useful information seemed to come from an A-scope type presentation. This consists of echo return versus range on an oscilloscope. The range gating method could be extended to more and smaller range increments until tactile scanning of numerous sensors would give a tactile A-scope presentation.

Range Requirements

Originally it was thought that the blind person would be primarily concerned with obstacles and especially nearby obstacles. Work by the Stromberg-Carlson Company revealed that, "A blind subject . . . walked with much more confidence if the guidance device gave no indication of objects beyond eight feet, than if he had to sort out and interpret information indicating many distant objects', and further that, 'there was a large amount of information about distant objects that was of no immediate use and actually caused confusion."[4] With this information, it was decided that initially the range would be limited to 25 feet with

[4]Slaymaker, F.H., and Meeker, W.F. "Blind Guidance by Ultrasonics", Electronics, May, 1948.

provision for changing this maximum range as necessary.

II. APPROACH TO DESIGN

In accordance with the preceding design criteria, 40 Khz was chosen as the operating frequency, and solid state devices, piezo-electric transducers, and tactile read-out devices were to be used. Neither a library search for past work on the subject nor correspondence with other investigators working in the field produced much circuit information. Previous work, which was available, involved cumbersome, tube-type devices with little applicability for solid state circuitry. Current devices are commercial in nature, and covered by patent rights. Literature concerned with ultrasonics invariably reveals an assortment of articles confined to the study of the intricate system used by the bat for navigation. Ultrasonic burglar alarms, garage door openers and other consumer items are also to be found in the literature. Some of these gave circuit diagrams or at least concepts of the transmission and reception of ultrasonic waves.

With this background and some experience in electronics the project was divided into four segments (1) receiver, (2) transmitter, (3) timing circuits, and (4) readout circuits. Since only a meager amount of information was available from past work, design centered about input-output relationships. Thereupon, a combination of electronic circuit design and emperical solutions were implemented for each segment, as will be outlined in subsequent chapters of this paper. For example, the receiving transducer output was known within limits, thus determining the receiver input. Any useful output from the receiver would have to be processed information of an amplitude of about 1 volt. Power to the receiver would be from batteries and minimal. The required gain for

the receiver was computed, the type of detection determined and a rough circuit block diagram drawn. Input/Output relationships essentially specified the receiver. A gain of about 100 db would require 3 to 4 grounded emitter transistor stages plus a stage for processing or wave shaping. The voltage and current requirements could be estimated to be in the range of 10 volts and 5 milliamperes.

The system was then to consist of a portable, solid state, self contained, battery operated, ultrasonic radar system featuring tactile readout.

CHAPTER III

IMPLEMENTATION

I. RECEIVER

At the outset, it must be stated that much of the receiver design was emperically arrived at. Initially, the relay control receiver circuit from an ultrasonic burglar alarm was tried. This receiver was designed to amplify ultrasonic waves from a piezo-electric transducer to a sufficient level for relay control.

Initial tests were conducted using this receiver modified for use with available transistors. It was found rather quickly that gain and noise were too little and too much respectively. It was decided that special low noise transistors would be tried and a low noise preamplifier added.

Receiver gain requirements were based upon the following computations:

Transmission (100 mw input)	27 DB
Path attenuation (50 ft, @ .32 DB/ft)	-16 DB
Spreading (-20logR)	-34 DB
Reception (-57 DB vs 1 volt/microbar)	-57 DB
	-80 DB
Additional estimate of coefficient of reflection, aspect ratio	-20 DB
Total required receiver gain	100 DB

Based upon a nominal 5 DB signal to noise ratio for the receiver, it was decided to use an FET front end, followed by 3 grounded emitter stages of approximately 35 DB gain each. The FET front end was allowed a gain of 25 DB. Thus, a maximum gain of about 130 DB was to be available. This would be more than enough for the requirements outlined above,

giving some margin with which to work.

The detection circuit consists of an emitter follower operating into a combination envelope detector and pulse amplifier. This scheme worked well initially and is used in the final circuit in preference to various other circuits tried.

Initially, the FET front end was connected in a so-called low-noise circuit; its "drain" being fed by a constant current source. The circuit operated at a recommended 27 volts. Further experimentation showed that the S/N ratio did not suffer appreciably when the constant current source was eliminated and the applied voltage reduced to 9 volts. For simplicity, the latter circuit was adopted for use in the final receiver design. Other low noise front end circuits were tried but none gave better results than the FET.

To further reduce the noise problem, tuned stages were tried to narrow the bandwidth of the receiver. Without such tuning, the entire receiver acts as a wide-band amplifier with an excessive noise bandwidth. With tuned stages, of course, gain within the desired passband increased considerably, to almost 40 DB per stage. Inevitable feedback problems resulted from so much gain on a small circuit board (2" x 3"). Detuning the final stage did not reduce this feedback problem. Experimentation with various circuit configurations resulted in a satisfactory compromise. This consisted of narrowing the bandpass with series tuned emitter bypass circuits. This type circuit was used in the first two transistor stages.

As may be noted in the manufacturer's specifications for the transducers, there are three methods of coupling to the transducers: shunt tuning, series tuning or untuned. With no tuning, the front end is

excessively noisy. Series tuning was tried but suffered two drawbacks, (1) the required inductors were physically large as were the associated capacitors, (2) a lower gain resulted when using the series tuned circuit. Shunt tuning with an 18 millihenry choke proved to be far superior.

Due to the high gain and small size requirements feedback was a constant problem. Therefore, in the final design toroidal inductors were used throughout along with liberal shielding, decoupling, and bypassing.

Initial testing of the receiver with the pulsed transmitter and adjacent transducers brought to light another problem. The receiver transducer would ring following the direct reception of the outgoing pulse thereby limiting the shortest possible range. Furthermore, reflected pulses from nearby objects tended to overload the receiver, extending the received pulses in time and therefore blocking out much information. To counteract both effects combination TR and AGC systems were tried. Among the TR arrangements were series and parallel transistor switch arrangements at the receiving transducer. Neither worked well due to increased feedback tendencies. AGC systems with receiver gating would be the ultimate answer. A range variable gain control (STC) was being developed by the investigators, but time did not permit including it in the final receiver design.

Other receiver designs were tested but did not prove to be satisfactory. For example, following the approach of Pye and Flinn, a superheterodyne circuit was developed.[1] The amplified 40 Khz signal was

[1]Pye, J.D., and Flynn, M. "Equipment for Detecting Animal Ultrasound." Ultrasonics, Vol 2, Jan-March 1964, pp. 23-28.

mixed with a 415 Khz signal from a crystal oscillator, and the resulting 455 Khz signal amplified with a Miller integrated IF strip. Two difficulties prevented the use of this circuit. The system was operable and the use of the Miller IF strip appeared economical from size, cost, and ease of construction. However, mixer noise was excessive, and the necessity for a crystal oscillator unduly complicated the circuitry. For these reasons and because further pulse shaping circuits were still necessary, this approach was not as desirable as the simple series tuned emitter circuits. Pye and Flinn state that, "Mixer noise is not troublesome if preceded by a signal frequency gain of about 10 in the microphone preamplifier."[2] Their receiving device was designed for the direct detection of bat and insect sounds. They were not working with signal levels as close to the ambient noise levels and in general less preamplifier gain was required before mixing.

The noise problem was greatly reduced, as was the necessity of high gain, when it was found possible to increase the transmitter power from 100 milliwatts average to 500 milliwatts average. Furthermore, consultation, testing, and past work indicated that a blind guidance device was most effective when presenting information out to a range of 8 to 10 feet.[3] Beyond this range information is not only ambiguous and misleading, but is also confusing and unnecessary.

Various forms of signal processing were used in attempting to recognize weak signals. If cost and size were not important, it is probable that these techniques would have to be developed even further. For

[2]Ibid., pp. 27

[3]F.H. Slaymaker and W.F. Meeker. Blind Guidance by Ultrasonics. Electronics (May 1948) pp. 76-77.

example, in trying to pull in and process weak signals, A-scope presentation revealed targets visible beneath the noise level. When receiver gain was raised to a sufficient level to key the readout devices, the noise pulses keyed on all range gates as well. Also, interference, such as the synchronizing signals sent to the laboratory clocks saturated the receiver, keying the readout lamps or vibrators. In order to achieve detection of the desired low level signals, a minimum pulse width detector was built of integrated circuits. This can be thought of as a crude form of correlation, in which the output of the detector is present only when the input pulse has the same pulse duration as the transmitted pulse. This circuit proved quite effective, but required five more transistors for each gated readout channel.

Atmospheric fluctuations cause very large signal variations in amplitude.[4] The use of pulse integration after detection, greatly stabilized the returned echo and a higher probability of detection was achieved. This process is not only elementary but a well documented and standard radar technique.[5] A more complicated system of integration, that aided in information presentation was the use of a multivibrator, synchronized to the pulse repitition frequency by the returned echo. A given number of returned echos would turn the multivibrator on. It would remain on and continue to oscillate until the echos were absent for a second given period. In this manner, a solid signal appeared to be present in spite of atmospheric variations. Ambiguity in this system along with detection probability problems are, of course, obvious. All of

[4]Slaymaker and Meeker, op. cit., p. 78

[5]Skolnik, M.I., "Introduction to Radar Systems." New York, McGraw Hill Book Co., Inc. 1962.

these processing schemes were finally discarded because of the complex circuits required for their implementation. The final receiver utilizes simple exponential integrating circuits.

Components within the receiver section are non-critical. Both NPN and PNP transistors have been used with good results. The front end FET has been tried with various biasing schemes and also seems relatively non-critical. The 18 millihenry choke should be very close to that value, since this is the optimum for good front end performance. The series tuned circuits in the emitter leads of the transistor amplifier stages should be resonated, although there is sufficient gain margin within the receiver so that off-resonance does not seriously affect performance.

II. TRANSMITTER

The transmitter section of the aid had to provide a one millisecond pulse every one hundred milliseconds. The output power had to be one hundred milliwatts average at a minimum. Further requirements were to use the MASSA TR-7 crystal transducer as the output element, and provide for external triggering of the transmitted pulse.

The TR-7 crystal transducer is manufactured for television remote control service. They were chosen for low cost, availability, and reasonable transmission patterns. A complete specification sheet for these transducers is included in the appendix. The maximum power these units can sustain is one half watt continuous, and five watts at a ten percent duty factor. No data was included as to peak power capabilities or input impedance. Since these units are piezoelectric devices, they would have a peak voltage, or peak power limitation. This was proven to be true during the course of transmitter design and testing. The TR-7 was loaded with an 18 millihenry choke and the input impedance measured at

resonance. This was found to be 5.7 Kilo-ohms. The quality factor of the loaded circuit was then approximately 8 at the resonant frequency of 40 Khz.

Several different circuit configurations were considered for the transmitter. Included were:

a. free-running oscillator followed by a keyed amplifier

b. keyed oscillator and amplifier

c. keyed power oscillator.

The first circuit tried was the free-running oscillator and keyed amplifier. This circuit allowed initial testing of the transducer and the receiver, but it did not perform well. A major difficulty was signal leak through and isolation. Unless several stages of isolation were used, signal voltage appeared at the transducer, resulting in some residual output during the required off periods. In addition, extensive shielding would have been required to prevent the oscillator signal from entering the high gain receiver. The circuit is shown in block form in figure 1.

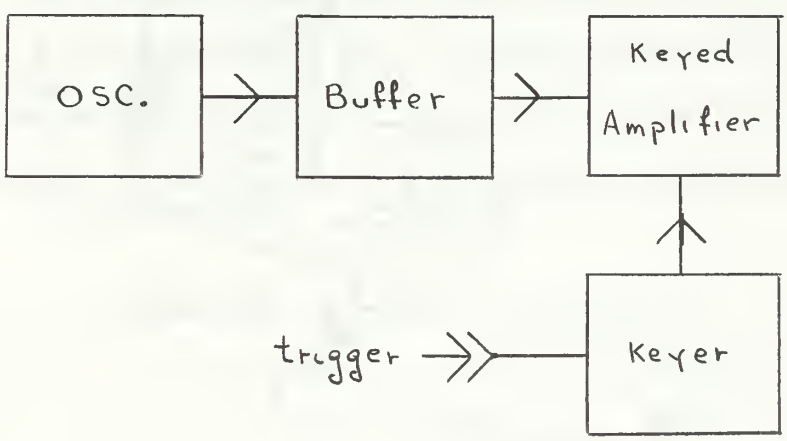

Figure 1

This circuit did allow measurement of the peak voltage capabilities of the transducer. This measurement was in part qualitative and is by no means an accurate measure of the actual breakdown voltage of the crystal. The supply voltage of the amplifier was increased, while observing the transducer voltage waveform, and listening to the transducer. Although the 40 Khz signal is not audible, the transient turn-on and turn-off is. With 800 volts peak-to-peak across the transducer, severe vibrations were audible. This voltage level was fairly independent of the pulse duration, and was chosen as the maximum sustainable for future circuit designs.

The logical advance from the first circuit was to key the oscillator, as well as the amplifier. Oscillator transients resulted that degraded the shape of the transmitted pulse, and caused a frequency modulation of the pulsed signal. The narrow band receiver employed for detection reduced the effective bandwidth of the returned echo, due to the frequency modulated component on the transmitted pulse. This resulted in a lowering of the effective S/N ratio at the receiver.

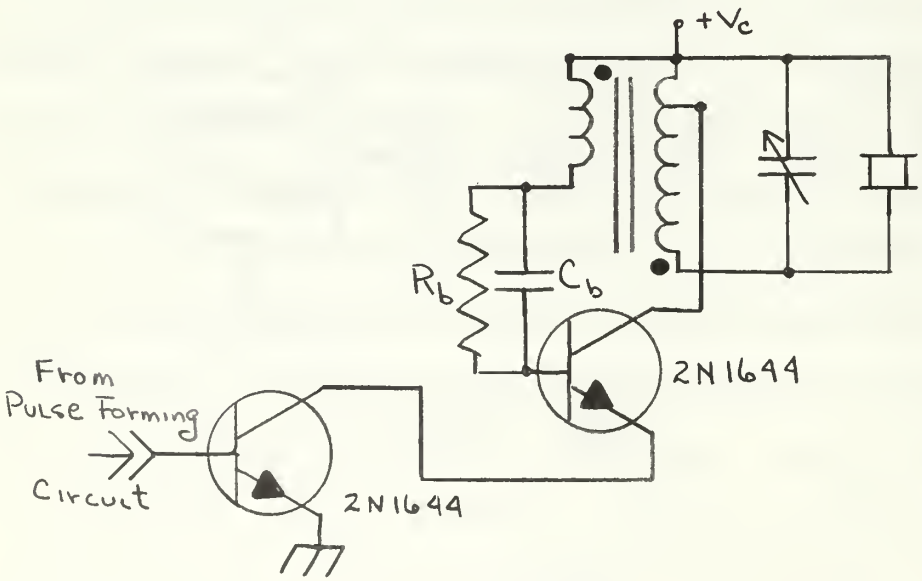

Figure 2

By this time, it was obvious that the transducer proper should be the controlling element for the oscillations. However, a power oscillator was not tried first, due to anticipated oscillator starting difficulties. A tickler feedback oscillator was built as shown in Figure 2.

This circuit showed good starting characteristics after proper adjustment of R_b, C_b. This adjustment was done experimentally while observing the transducer voltage. It was observed that optimum voltage across the transducer did not coincide with optimum wave shape of the pulse. An interesting investigation for a future project would be that of optimized power oscillator keying.

In order to achieve a peak-to-peak transducer voltage of 600 volts, a supply voltage of 60 volts was required with the design shown in Figure 2. The collector tap point was then lowered to enable the use of a lower supply voltage. When this was done, it became impossible to increase the transducer voltage above about 100 volts peak-to-peak, with a supply voltage of 12 volts. Various combinations of collector tap points, feedback winding ratios, and R_b, C_b combinations were tried, but to no avail. Transistor type 2N1613's were then tried in the circuit with similar results. Both the 2N1644 and the 2N1613 are in the two to three watt dissipation class, and have high collector to base voltage breakdown characteristics. These devices were capable of producing the required power output at high supply voltages but not at low voltages.

The reason for the difficulty lay in the saturation resistances of these transistors at high collector currents. In order to achieve the output power desired at 12 volts a peak collector current of 1.5 amperes was required. These devices were current limited by the collector

saturation resistance and the required peak collector current was never obtained.

The answer, obviously, was to use transistors with very low values of saturation resistance and high current ratings. Transistor type 2N1022 was substituted for both oscillator and keyer. After adjustment of the bias network, a peak-to-peak transducer voltage of 700 volts was obtained with the nominal 12 volts supply voltage. The 2N1022 has a low leakage current, and it was only necessary to operate the keying transistor class B to achieve good shut off of the oscillator. The oscillator operates over the voltage range of 2 to 20 volts, and exhibits no starting difficulties over this range. At the higher voltage levels the transducer is in danger of voltage breakdown as stated earlier.

The frequency of the oscillator can be tuned by C_1, a trimmer capacitor across the tank circuit. The final circuit was built on a printed circuit board and shielding provided around the oscillator section.

The pulse forming circuit for keying the oscillator consists of a simple monostable multivibrator, and an emitter follower. As shown in Figure 3, direct coupling is used from the monostable to the emitter follower, and then to the keying transistor. The off time of transistor Q_2 is adjustable between .2 milliseconds and 1.0 milliseconds. A keying pulse is formed each time a negative trigger pulse is received from the timing circuits.

III. TIMING CIRCUITS

The requirements of the timing circuits were to: (1) provide a stable pulse to the transmitter for keying at the pulse repitition frequency, and (2) provide gate signals for use in the diode logic circuits

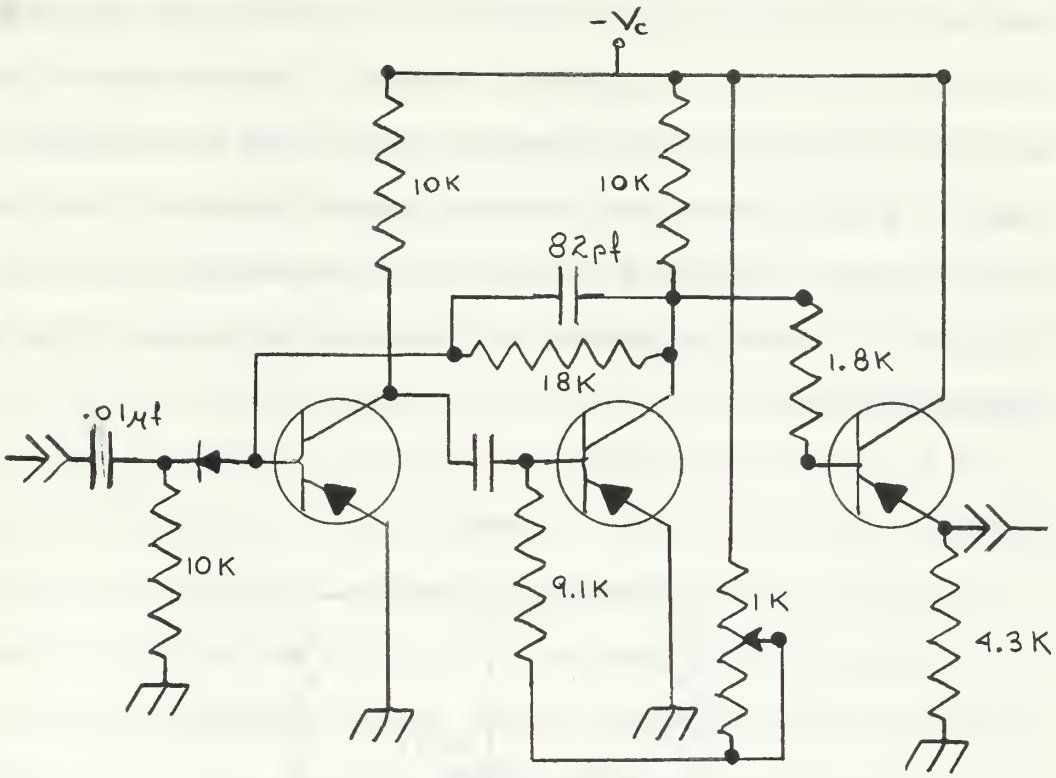

Figure 3

implemented for digital readout. In addition, the circuitry had to be such that expansion to a greater number of readouts could be accomplished with a minimum of effort.

Initial design consisted of a five stage self triggering ring counter, employing monostable elements. This circuit required a starting pulse to begin oscillation. In addition, the circuit was very voltage dependent. The biggest disadvantage of this type ring counter was the difficulty in element expansion. For this reason, it was decided to use bi-stable elements driven by a clock source.

Micro-logic elements were the natural choice for this application. Fairchild micro-logic medium powered elements were used so that output loading would not adversely affect the operation of the timer.

The clock circuit consists of a uL 914 dual input NAND gate, cross-coupled to form an astable multivibrator, whose frequency is six times that of the basic pulse repitition frequency. If more than six gates are to be used then the clock frequency is 56 Hertz multiplied by the number of gates desired (for a maximum range of 10 feet). The clock generator is shown in Figure 4. Only five of the six gates are used; the first one is a blanking interval to allow receiver recovery from the transmitted pulse.

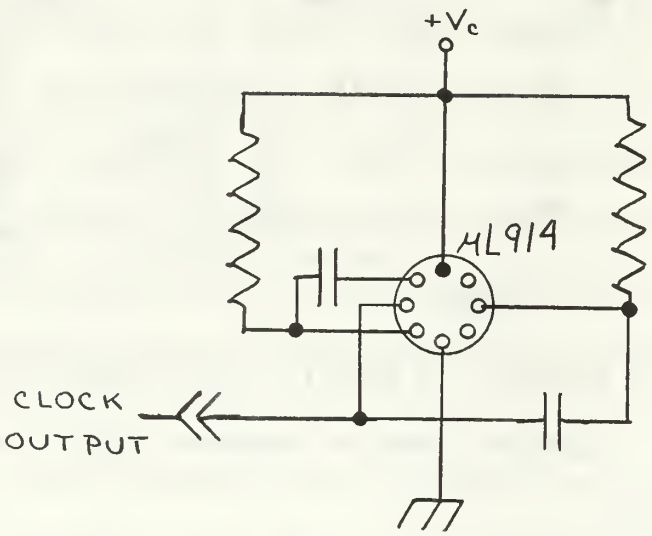

Figure 4

Fairchild uL 923JK flip-flops were used for the elements of the ring counter. The diagram and logic for these micro-logic elements are shown in the appendix. The ring counter logic and circuit are also shown in the appendix. The uL 923 elements allow the use of a preset pulse or voltage level to set the ring counter in its initial 100000 state. Removal of the preset voltage and subsequent application of the clock pulses will cause the one level to move around the counter in the

desired manner. This circuit was operated over an eight hour period with no errors in the count, ie: no additional ones entered the ring counter due to noise or change in battery voltage.

The output of the last stage of the ring counter is differentiated to provide the negative keying pulse for the transmitter.

The clock generator and ring counter operate at a nominal voltage and current of 3.5 volts, and 130 milliamperes. A power consumption of 455 milliwatts. This is small enough to allow operation from conventional dry cells, but a rechargeable cadmium-nickle cell would be preferred in a production model of the aid. If further power consumption reductions were needed, low power micro-logic elements produced by Fairchild could be used with a ninety percent savings in power.

The clock generator is also voltage sensitive, and zener voltage stabilization is required to maintain a constant pulse repitition frequency. These circuits were also built on a printed circuit board, and the configuration is shown in the appendix.

IV. READOUT

Solution of the human-device interface problem appears virtually impossible. Certainly, attempts to present information aurally or tactilely will never be fully satisfactory. The bandwidth and information rate of the human eye is unquestionably much greater than that of the other senses. While a radar system can be designed to virtually any degree of sophistication, presentation of the information is the limiting factor, even in a normal individual. It is a known fact, that the handicapped develop much greater facility with the remaining senses. Even with this fact in mind, there is a tremendous psychological and physiological barrier in presenting information originally meant for

visual presentation. The psychological and physiological aspects of the human-device interface are the subject of continuous study of many scholars and institutions. St. Dunstans, Haskins Laboratories, Massachusetts Institute of Technology, and Stanford University are among those actively engaged in the optimization of human-device interface problems. The investigators have only attempted a solution which is obvious, practical, economical, and like many other proposed solutions, rather inadequate. It is left for others capable of evaluating the psychological and physiological aspects - those with adequate facilities and background - to solve the interface problem.

Of the many possible solutions, tactile stimulation will only be considered. As previously stated, it is the considered opinion of others that the aural channels of the blind must be available for normal communications, and listening to environmental sounds. Tactile stimulation was considered from really only three possibilities: (1) vibration, (2) sense of touch (indentations, or raised projections), and (3) mild electrical shock. Essentially, all three types of presentation are similar and equally adapted to presenting the available information.

Being of the opinion that the maximum information from this device would be an A-scope presentation, it was initially decided that readout would be similar in form and that the subject would be presented a tactile A-scope to be scanned by the fingertips. Correspondence with manufacturers of miniature solenoids and vibrators indicated that aquisition of such devices suitable for this specific use was not possible without extensive research and development. Experimentation with hand made devices of this type did not give satisfactory results. In addition, the power consumption would be greater than portability would

allow. Communication with Dr. J. G. Linvill of the Stanford Research Institute revealed a more plausible method.[6] This is the use of piezoelectric matrices providing vibrating elements. Dr. Linvill has used such matrices for Braille reading devices where up to 48 pins are set into a 6 by 8 matrix which is scanned by the finger tip to read Braille characters. Each pin uses only 30 microwatts of power.

A system of this type is then the one proposed for any further development of this or other blind guidance devices. Due to the rather high cost of fabrication, and the time involved in its manufacture, this has not been used in the design of this blind guidance device. Also, this study is a development and feasibility study, and not one of full implementation. Therefore, the investigators have chosen to limit the number of gates to five and to use a substitute method of information presentation - - vibrators. Modified hearing aid earphones were chosen for the prototype model. These were modified only in that the diaphram was made fully available to the fingertip.

It should be noted that miniature loudspeakers, crystal earphones, and magnetostrictive earphones, were all tried. The ones selected were high impedance devices and seem to have the best characteristics.

The electronic decision of the presence of an echo within each range gate is produced by AND gates for each range increment. These consist of two ordinary diodes. The receiver output is fed to one diode of each pair while the timer feeds a different gate signal to each of the diodes of the pairs. When a signal return is present within a given range increment, there is an output from the gate. Otherwise there is

[6]Linvill, J.G. and Bliss, J.C., A Direct Translation Reading Aid for the Blind, Proceedings of the IEEE, Vol 59, No. 1. Jan. 1966, pp. 40-51.

none. Since the receiver output is essentially 2 volts as is the timer, there is little cross-loading effects in the AND diode logic circuits.

This 2 volt level pulse is then amplified sufficiently to drive the output transducers. It was important that the AND gates not be loaded heavily, so a Darlington pair was used as the driving element. Since the output transducers are high impedance (2000 ohms) earphones, a good collector load is provided and the amplifiers work anywhere from 3 to 70 volts depending on the desired output.

Rather than build separate oscillators to drive the transducers, the basic PRF provided by the returned echo is used as the vibration frequency. While this frequency is far from optimum, it is none the less, useable and simple. The PRF is 56 Hz. This frequency requires about 6 microns of movement for tactile detection, while the optimum frequency of 300 Hz. requires 1 micron of movement.[7]

Using this method of readout, each sensor requires 1 to 2 milliamperes at 6 volts and correspondingly higher power for greater diaphram excursions. This power requirement is far greater than the 30 microwatts required by a crystal matrix, but the latter might require a somewhat more complicated driving arrangement.

The transistors used in the transducer driver unit are not at all critical. Silicon units were used for their low I_{cbo} and power handling capabilities. Almost any transistor could be used. The readout section of the project was undoubtedly the least critical component and design wise. Few other circuits were tried, since this circuit seemed simplest and least expensive.

[7]Linvill and Bliss, Ibid., pp. 40-51.

It was suggested that five readout channels be used, one for each finger, and that a changing frequency be provided to present information as to target position within each gate. A workable system was developed using this idea. The returned echo was calibrated in voltage corresponding to range by combination with a sawtooth waveform. This voltage was then applied to a voltage to frequency converter. The system proved far too complex, power consuming and ambiguous. Five voltage to frequency converters were necessary containing five transistors each. An additional sawtooth generator was necessary as well as the additional gates. Furthermore, more than one target within a gate or the presence of a long target gave quite confusing information. This investigation proved that expansion of the number of range getes with simple yes/no information would be the wiser choice if more information was needed.

CHAPTER IV

RESULTS

An ultrasonic radar system suitable for blind guidance has been designed, built, and to a limited degree tested. This section of the paper will be concerned with the degree to which the original criteria have been met.

I. TESTING

Electrical and physical testing have been accomplished to a sufficient degree. The psychological and physiological aspects of the device have not been explored to a significant degree due to the lack of adequate facilities to do so and the lack of proper background to pursue such investigation. These latter aspects were beyond the scope of this study and are left to those institutions equipped for such a study.

Physically, this blind guidance device, hereafter referred to as BGD-1, is a portable, ultrasonic system contained in an enclosure 2 by 6 by 5½ inches and is shown in final form in the appendix. At a maximum range of 10 feet, the system will warn its user of obstacles of suitable size and orientation. Bearing information is provided by pointing the unit and range information by vibrations at each fingertip. The prototype unit gives yes/no information within each range interval of two feet and some indication of size of the object by the amplitude of the vibration.

Probability of detection is difficult to accurately evaluate since this is a function of size, reflectivity, orientation, range, surface smoothness, temperature, humidity, and type of scanning. For example, a perfectly smooth surface such as a very large metal plate might not give an echo if it is at an unsuitable angle to the unit, while a small

piece of thread perpendicular to the beam would. This result has been found generally true of ultrasonic reflections and is not a function of BGD-1.[1]

Oscilloscope echo forms from the returned echo are identical in shape to normal radar A-scope presentations. An undesirable phenomenon observed in this unit and in other ultrasonic ranging devices is the fluctuations in the returned echo.[2] Such fluctuations are a result of atmospheric disturbances such as air currents and are typical of ultrasonic wave propagation through air. The effect on reception is to make the readout variable in amplitude and sometimes intermittent.

A problem suitable for further possible refinement of BGD-1 is that of too much information. With the 60 degree beamwidth used, echos of the ground and surrounding objects not directly in front of the beam are returned. There are two ways of viewing this problem. First, it is possible to narrow the ultrasonic beam; to do so without loss, however, requires the use of a larger aperture. The use of a parabolic reflector is about the best method of doing so and in tests has proved highly effective. Of course, the obvious difficulty here is the very large sized "dish" required. The investigators discarded this idea after reviewing size requirements and looking at units built by others using such reflectors.

Secondly, if the beam is made narrow, it becomes necessary to train the subject in a scan technique. Unless this scanning is quite carefully accomplished, it is obvious that many obstacles may escape notice. Thus,

[1]F.H. Slaymaker and W.F. Meeker, "Blind Guidance by Ultrasonics", Electronics (May 1948), p. 78.

[2]Ibid.

this second view point reinforces abandonment of the narrow beam technique.

Some experimentation was done using directional microphone techniques.[3] Quasi-loaded tubes were affixed to the transducers in an attempt to limit the effective outgoing and incoming waves to those propagating in a direction perpendicular to the face of the transducer. The experiment was quite unsuccessful. Primarily, the loading led to losses which reduced the available power to the receiving transducer. Secondly, directional characteristics were not appreciably altered without long tubes. Thus it was concluded that beamwidth is an aperture problem that could be practically solved only through phased arrays of transducers or the use of parabolic reflectors. Both of these solutions are somewhat undesirable for miniature, portable equipment.

By limiting the range of the equipment to 10 feet, the effect of beamwidth was reduced At this range, the 60 degree beamwidth is about optimum for most obstacles. If it were later decided to provide a high range position on the equipment, reduction of the beamwidth might be worthwhile.

Physically, BGD-1 was subjected to moderately abusive treatment through impact and vibration with no adverse effects on operation. Electrically, overvoltages and undervoltages were applied and the unit operated for extended intervals again with no adverse effects.

Battery drain has been mentioned in other sections of the report. To recapitulate, the following are the power requirements of BGD-1:

[3]A.E. Robertson, "Microphones", New York, Hayden Book Company, 1951.

Receiver	27 milliwatts
Transmitter	500 milliwatts
Timer	500 milliwatts
Readout	150 milliwatts

Battery life will be a function of the type of batteries used. In the prototype only small dry cells were used. For production, a rechargeable nickle-cadmium cell would be desirable along with modification of the Timer to use low-power micrologic elements in lieu of the medium power units. Battery drain could thus be reduced from 1.177 watts to about 800 milliwatts. (This figure would be altered somewhat if an increased number of range gates were used along with piezo-electric readout transducers.)

Detailed circuit testing results have been covered in other sections of this report.

II. FEASIBILITY

Construction of BGD-1 is practical and straight forward. It should be possible to reproduce the entire unit as shown with identical results. BGD-1 could concievably be manufactured for less than $200 per unit. The following costs for components is the basis for this estimate:

2	2N1022	@ $7.00	$14.00
3	2N1259	2.50	7.50
15	2N1613	2.50	37.50
1	2N3822 (FET)	28.50	28.50
6	J-K flip/flops	1.50	9.00
2	Transducers	5.00 est.	10.00
4	18 mh toroids	5.00 est.	20.00

5	earphones	$1.25	$6.25
	Miscellaneous resistors and capacitors		10.00
	Total		$142.75

This itemization is based upon the components used. Most components are non-critical; those used happened to be readily available to the investigators. The estimated cost could be considerably reduced by using more reasonably priced components. For example, the FET used was the only one readily available and is a high quality 150 mcs. device. Many other FETs would be suitable substitutes since high frequency response is not necessary. Current FETs with good lower frequency characteristics are available for under $5.00. The 15 2N1613s specified for the receiver and readout are non-critical and could be replaced by practically any silicon NPN transistors Of all the various types tried, e.g. 2N1566, 2N1644, 2N706, 2N2218, etc., all were equally effective. Thus, the total receiver transistor costs could be in the range of $1.00 each for a total of $15.00. The transmitter transistors are somewhat more critical, particularly the 2N1022s, but even these could be replaced by cheaper low saturation resistance units for about half the price. Finally, the 18 mh. chokes could be obtained for about half the price estimated.

Of course, there are also some additional costs that would be incurred were BGD-1 to be considered for manufucture. Among these would be the recommended use of a ceramic matrix readout device and associated drivers. Given the great number of decisions that would be necessary prior to any thought of manufacturing, a true estimate is very difficult. However, it seems plausible that under any practical circumstances, BGD-1 could be manufactured for under $200 per unit.

CHAPTER V

RECOMMENDATIONS AND CONCLUSIONS

I. CONCLUSIONS

The investigators have considered only a small segment of the problem of blind guidance devices. As noted in Section One of this report, the problem is many faceted. It is doubtful that a true solution will ever be found in the realm of devices entirely external to the blind subject; the implication here being that physiological interfaces, e.g. direct nerve or brain connections will have to be made.[1]

There is a severe limitation to the amount and type of information that can be acquired practically, from the subject's environment, when compared with the wonder of the human's visual channels. Given even partial information acquirement, the interface problem of presentation of the information in quantity, quality and real time will undoubtedly be virtually unsolvable for some time to come. Certainly the great amount of research and effort presently being expended and already expended by many capable researchers attests to this fact.

BGD-1 acquires, in use, range, bearing and some degree of texture information. Presentation of range and texture through tactile stimulation, with presentation of bearing through manipulation, provide limited but useful information, and is to a great extent a function of ultrasonic propagation and not BGD-1. Limitations of BGD-1 include ambiguities present in any radar system, bearing ambiguities, range ambiguities, variation in echo return, close and long range limitations, etc. These problems have been enumerated herein and in the various references.

[1]W.B. Bishop, Environment Sensing, A New Approach to the Design of an Electronic Aid for the Blind." AFCRL 63-64.

Problems of an unsolvable nature, and very important nature, cannot be overcome with a simple system. In particular, step down information, e.g. an open manhole cover, cannot be obtained from this system - nor can this be obtained from similar systems. This is not an equipment limitation.

Finally, to adequately make up for deficiencies inherent in BGD-1, in infra-red devices, and in fact in all systems, it can only be inferred that the strong points of many be combined, i.e. that a number of devices be simultaneously incorporated in a true system. For example a subminiature television camera with a piezo-electric bimorph stimulator array could provide two dimensional "picture" presentation of the surrounding environment. In combination with a ranging device, it is possible that a blind person could be given sufficiently sophisticated information with proper interfacing to tactically "see". Even under these rather idealistic and somewhat impractical conditions, external devices as a substitute for the human eye would still be inadequate.

A retrospective look at the problem of blind guidance by the investigators, indicates that a broader viewpoint is needed for environmental sensing and transmission to the individual. Such retrospect is hard to acquire except through experience. Having acquired much, the investigators can hardly conceive of less than continued large scale investigation of the problem with a systems approach. While many institutions and individuals are contributing invaluably to the problem and will undoubtedly continue to do so, only time or an intensive coordinated effort seem likely to produce a system of great value. Even then the final evaluation and usage of such a system will hinge upon the physcology of the handicapped blind.

II. RECOMMENDATIONS

It is recommended that the final form of BGD-1 be cane mounted with tactile readout in the handgrip. In this manner it would provide a valuable adjunct to the cane and vice versa, in that the cane would continue to warn the user of step down and detailed close-in information.

Recommended for future inclusion in BGD-1 would be the use of an increased number of gates as indicated previously with an array of piezoelectric output transducers to simulate A-scope presentation. Furthermore, a "long" range switch might prove valuable. Such a switch could easily be incorporated.

Some use might be made of an array of transducers which could be phased for narrowing the beam if such narrowing proved useful.

Finally, an STC system might well be added to the receiver section of the device to increase sensitivity as a function of range Such an improvement was in progress with BGD-1, but was not incorporated due to lack of time.

Considering the time spent in the development of this device, it is felt that much was accomplished, much was learned and that in some way a contribution was made to the study of the problem and its solution.

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APPENDIX I

SPECIFICATIONS SHEET

BGD - 1

Receiver:

Frequency	40 KHz
Gain	100 DB
Power Requirement	100 Milliwatt @ 9 volt
Number of Stages	5
Input Impedance	greater than 100 Kohm
Output Level	1 volt pulsed
Signal to Noise Ratio	not measured

Transmitter:

Frequency	40 KHz
Pulse Repetition Rate	56 Hz
Power Output	½ watt average
Pulse Duration	½ millisecond
Stages	5
Frequency Control	Crystal transducer
Keying	Transistor switch
Voltage	6 volts

Timer:

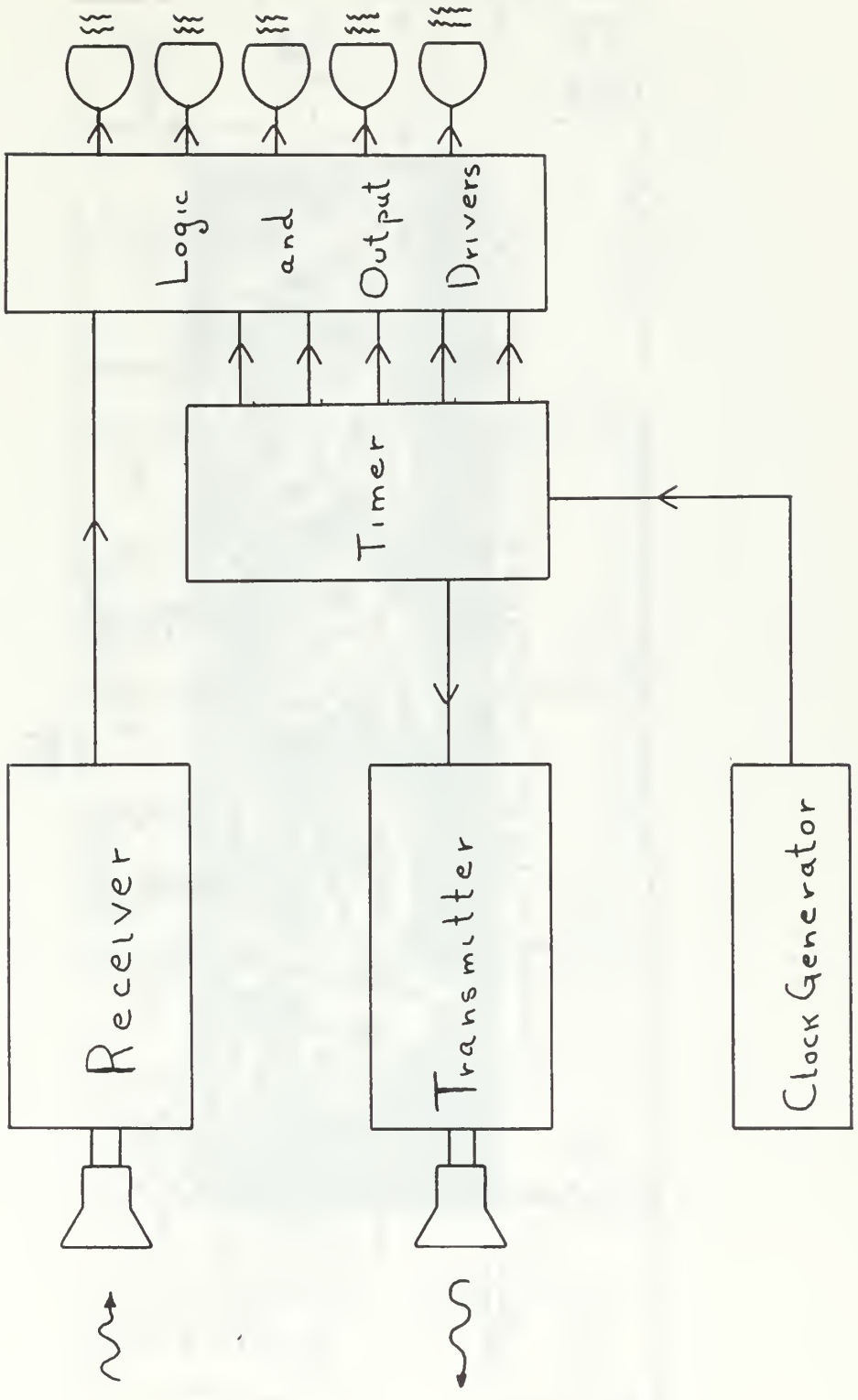
Type	6 stage ring counter
Purpose	Provide basic PRF, and 5 range gates

SPECIFICATIONS SHEET
(continued)

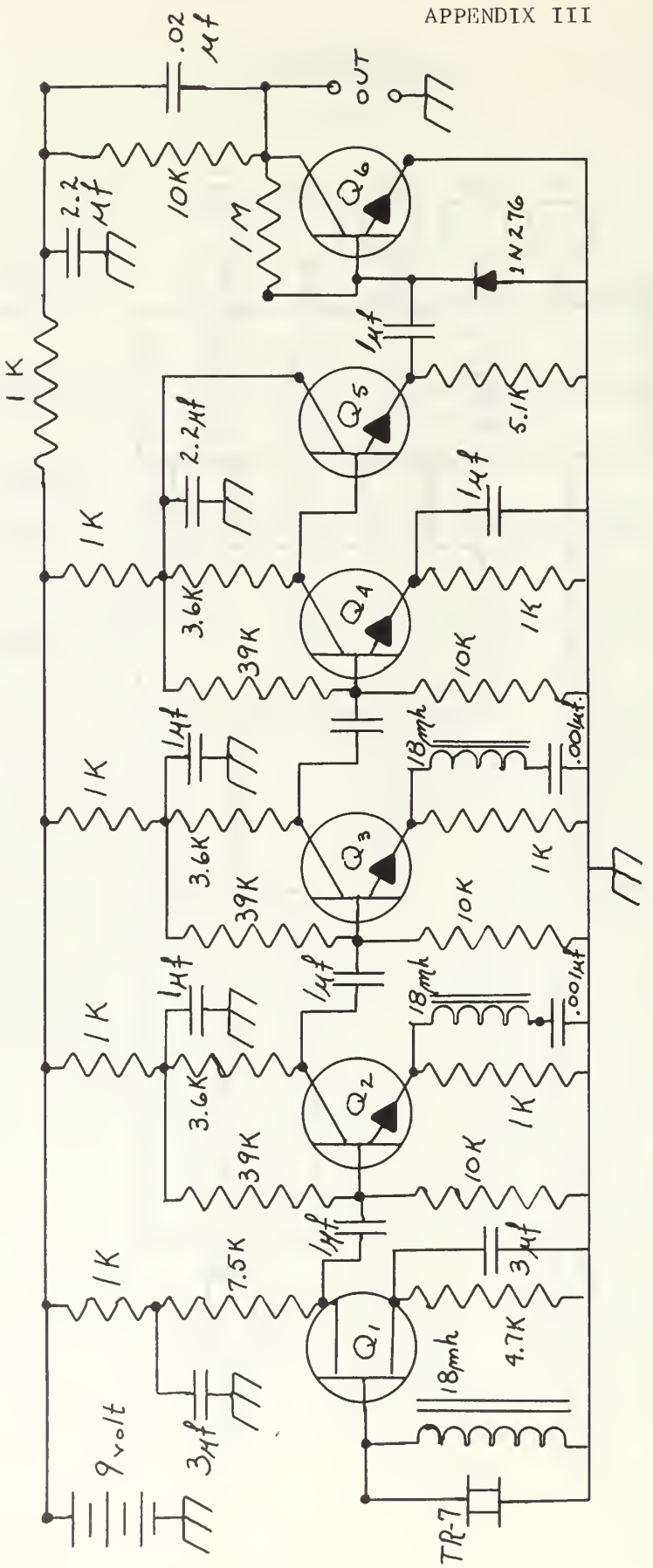
Readout:

Type	tactile vibrators
Logic	AND gates for receiver/gate coincidence
Drivers	2 transistors in Darlington configuration
Voltage	9 volts
Power	50 milliwatts average

APPENDIX II

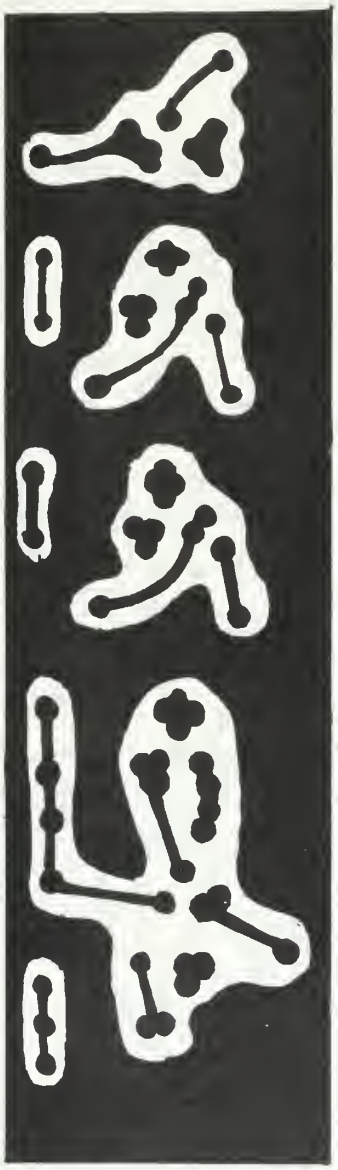


BLOCK DIAGRAM

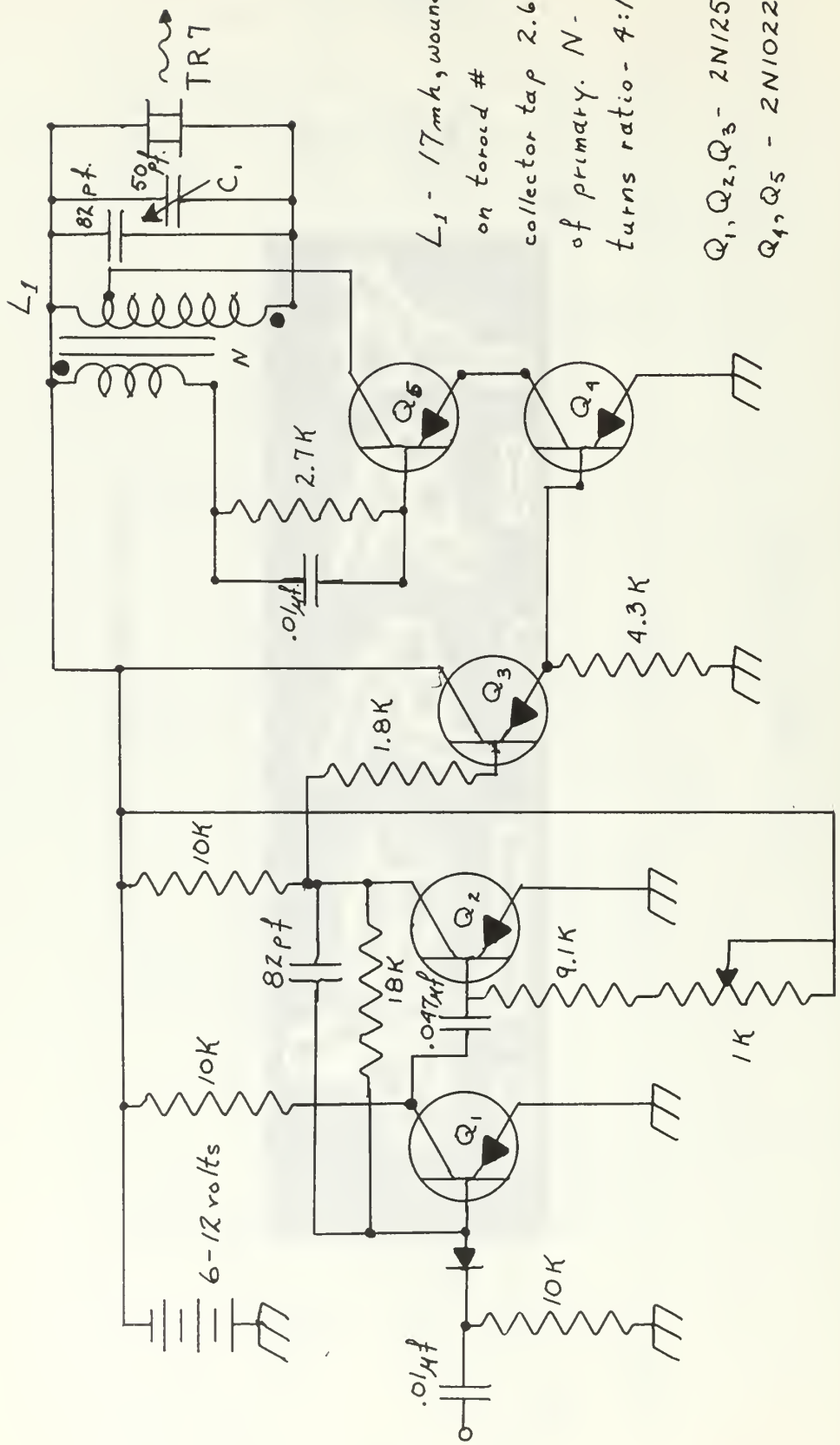


RECEIVER SCHEMATIC DIAGRAM

APPENDIX IV

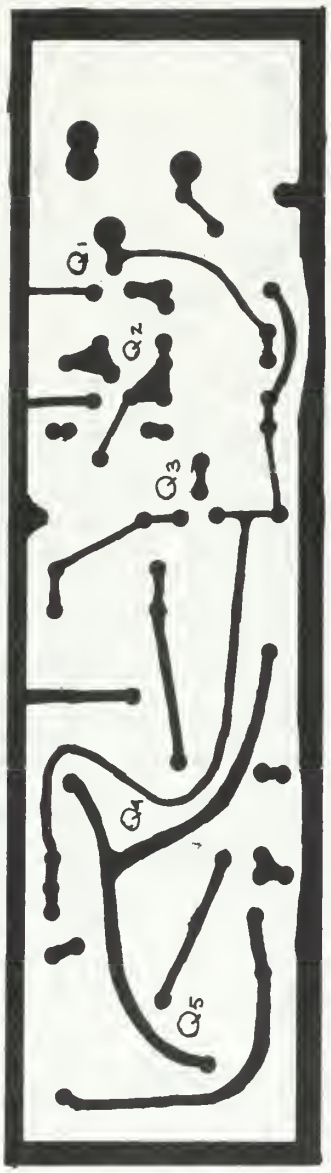


RECEIVER CIRCUIT BOARD LAYOUT



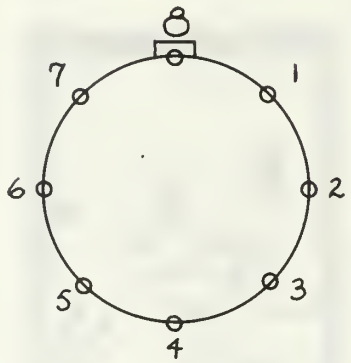
TRANSMITTER SCHEMATIC DIAGRAM

APPENDIX VI



TRANSMITTER CIRCUIT BOARD LAYOUT

Fairchild μL 923



Pin

1 Set

2 Clock

3 Reset

4 Ground

5 $\overline{Q}$ - output inverse

6 Preset

7 Q - output

8 (+) Pos. supply voltage

A (+) positive voltage on pin "6" will put pin "7" in the "0" state.

Set Reset Output

(1)	(3) $t = n$	(7) $t = n+1$
1	1	Q^n
1	0	1
0	1	0
0	0	$\overline{Q^n}$

1 - high voltage state

0 - Low voltage state

Q^n - output at $t = n$

$\overline{Q}^n$ - output inverse at $t = n$

FAIRCHILD uL923, BASE DIAGRAM AND LOGIC

Truth Table

Output t=n+1						Input t=m											
						A		B		C		D		E		F	
A_5	B_7	C_7	D_7	E_7	F_7	1	3	1	3	1	3	1	3	1	3	1	3
1	0	0	0	0	0	1	0	1	0	0	1	0	1	0	1	0	1
0	1	0	0	0	0	1	0	0	1	1	0	0	1	0	1	0	1
0	0	1	0	0	0	1	0	0	1	0	1	1	0	0	1	0	1
0	0	0	1	0	0	1	0	0	1	0	1	0	1	1	0	0	1
0	0	0	0	1	0	1	0	0	1	0	1	0	1	0	1	1	0
0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1

Circuit Connections:

$A_1 = F_5$ $\quad A_3 = F_7$

$B_1 = A_5$ $\quad B_3 = A_7$

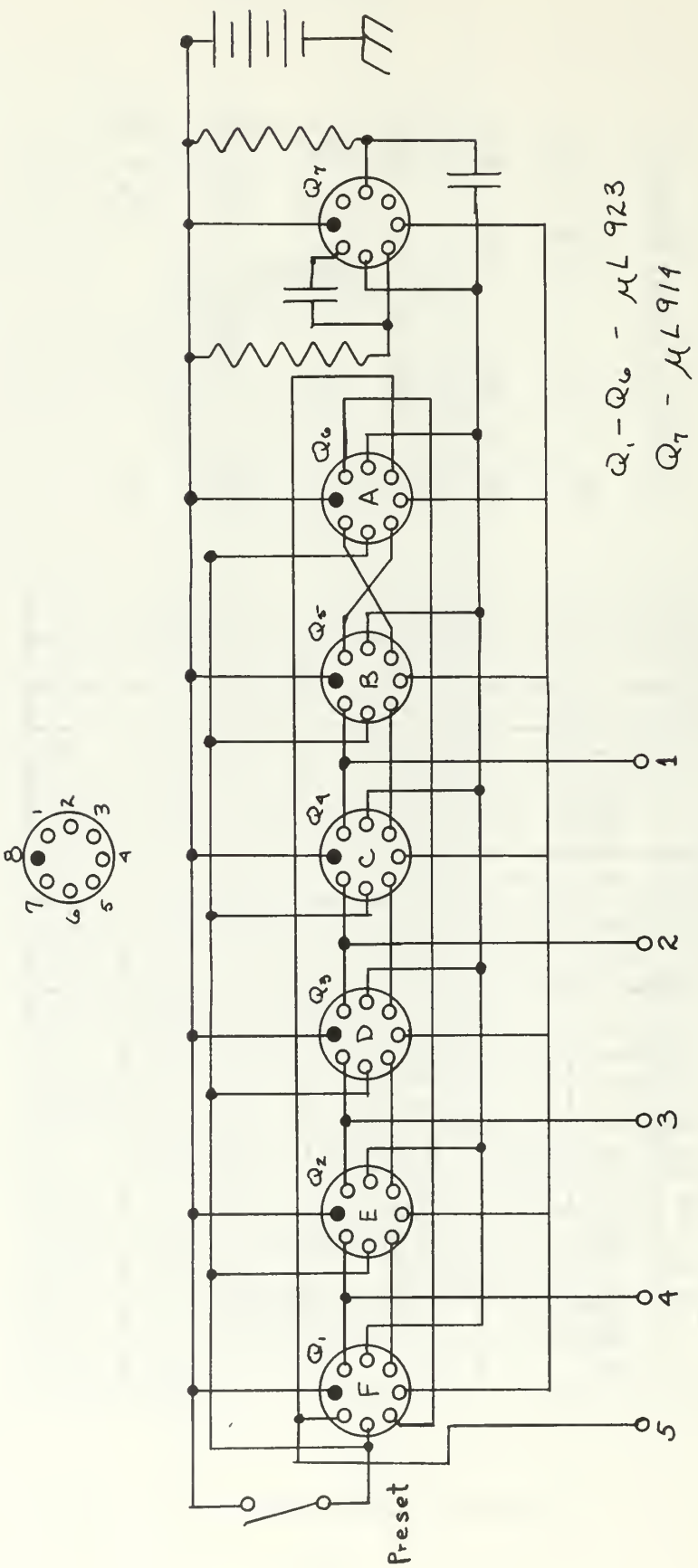
$C_1 = B_7$ $\quad C_3 = B_5$

$D_1 = C_7$ $\quad D_3 = C_5$

$E_1 = D_7$ $\quad E_3 = D_5$

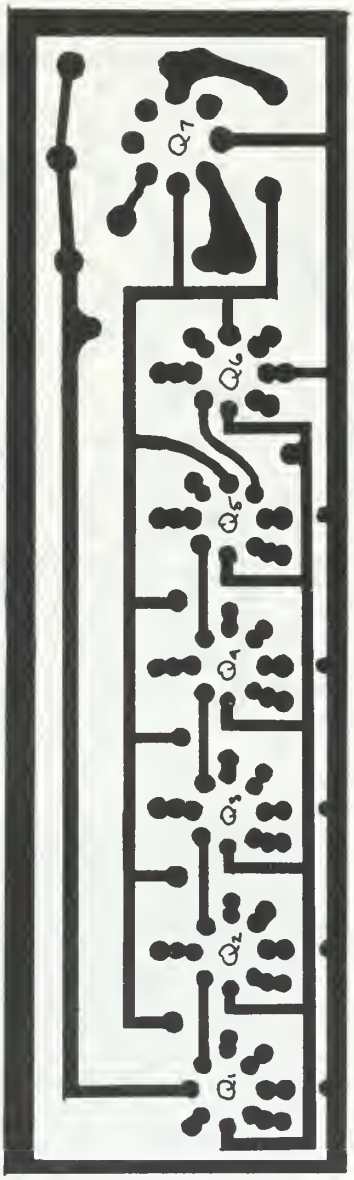
$F_1 = E_7$ $\quad F_3 = E_5$

TIMER TRUTH TABLE AND CIRCUIT CONNECTION REQUIREMENTS

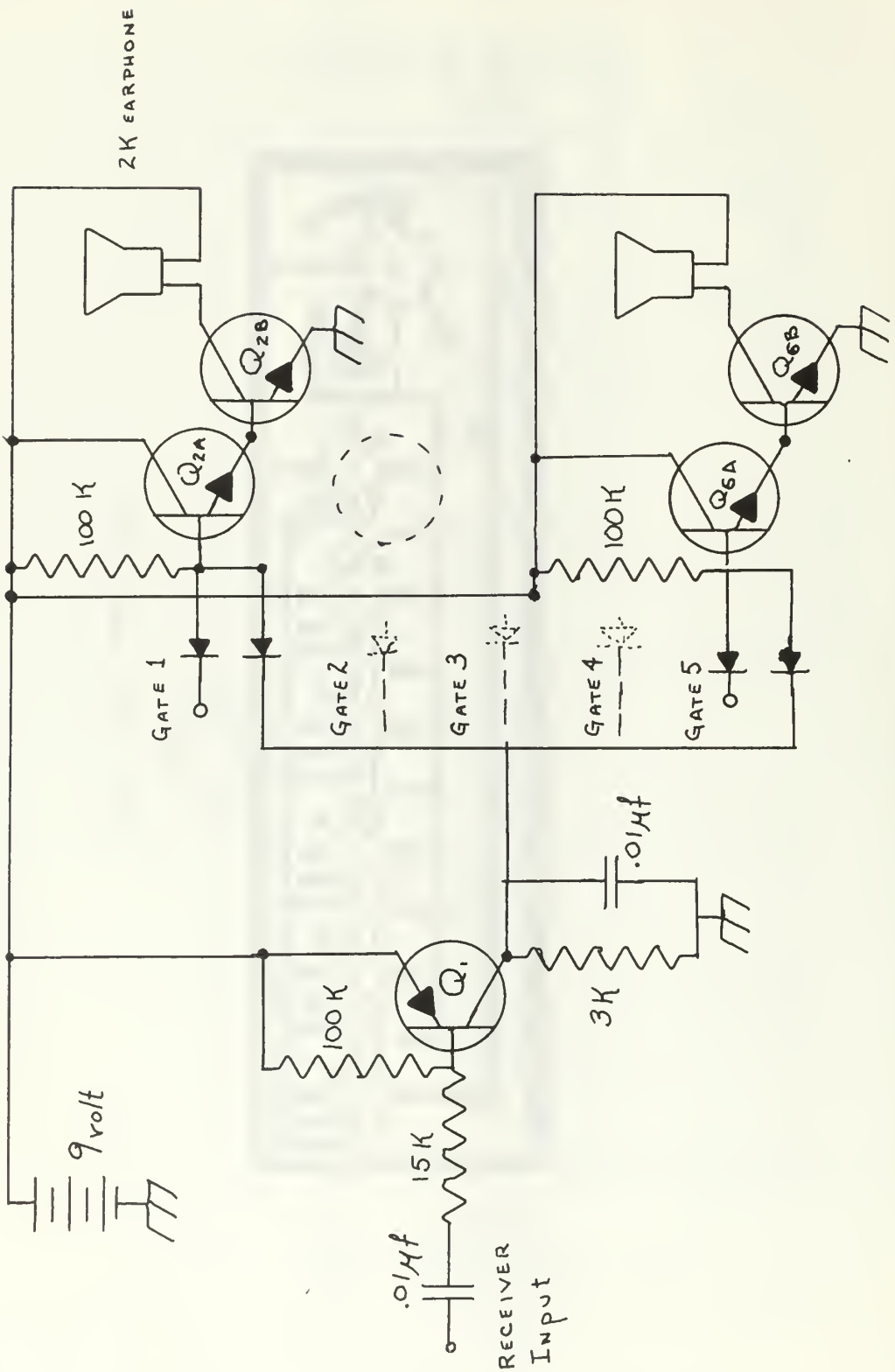


TIMER SCHEMATIC DIAGRAM

APPENDIX X

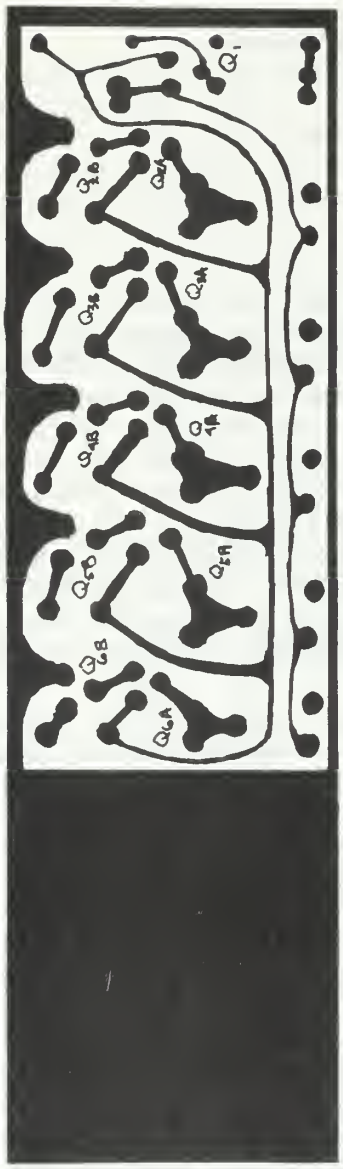


TIMER CIRCUIT BOARD LAYOUT



READOUT SCHEMATIC DIAGRAM

APPENDIX XII



READOUT CIRCUIT BOARD LAYOUT

L.Kay,B.Sc.,Ph.D.,MIEE, MIERE,
Professor of Electrical Engineering.

DEPARTMENT OF ELECTRICAL ENGINEERING
UNIVERSITY OF CANTERBURY
PRIVATE BAG
CHRISTCHURCH
NEW ZEALAND

29th July, 1966.

Lt.Cdr. John Wirtz,
Box 1265,
U.S. Naval Postgraduate School,
Monterey,
California, 93940,
U. S. A.

Dear Lt.Cdr. Wirtz,

Thank you for your enquiry - I was interested to learn that two of you are working on an aid for the Blind. This seems to be a subject which is receiving more attention these days and you are not the first to write to me requesting such information for your thesis. I appreciate that what you are doing is not a commercial project but, unfortunately, my work has progressed so far that a public organisation in England and a British manufacturer are now preparing production of the aid. All rights have been handed over to a public body to protect Blind people and as a result I am no longer in a position to give technical details of the device - this could only be done through the organisation and the industry concerned. At this stage it is unlikely that they would do so.

I am sure you will realise that at this critical point where the aid is being accepted by Blind organisations, various industries are interested in making the unit in addition to the one licensed to do so. We cannot therefore risk any leak, and I have had to treat all requests the same.

Nevertheless, there are some things I am prepared to tell you. I have been in this field for over six years now and I am in contact with the major organisations involved in research for the Blind. This is a problem which cannot be solved by devices which are not closely related to human behaviour and the sensory system. You are developing a pulsed system and, unless you are processing the received information very carefully, your man-machine interface will be very poor. In addition, a pulse of 1 milli-second has such a narrow band that it will be of little value other than as an 'obstacle detector'. Information could only be gathered through a wide band and at least an octave is required for more than just yes/no information.

The frequency in which you are working is in the correct region but I suggest you obtain the Research Report from the Haskin's Laboratory on Obstacle Detectors, as I am sure you will see that they

have probably made the unit on which you are working. A tactile readout is very limited in the information it can transfer - auditory readout is now recognised as being more promising. To give you an idea of the present state of the art, we here at Canterbury are developing units which will resemble sunglasses, camouflaging specially designed transducers to enable a blind person to view his environment over an arc of 60° or more through his binaural capabilities. I feel that it is in this area where more progress is likely to be made *now*.

I suggest you write to St.Dunstan's (Mr.R.Dufton, Director of Research), 191 Marylebone Road, London, N.W.1. England, and ask them for copies of the papers presented at a recent conference there, and also to Mr.Leslie Clark, Director, International Research Information Service, American Foundation for the Blind, Inc., 15 West 16th Street, New York 11, N.Y., who has an exhaustive bibliography available for people working in this field.

I hope I am not discouraging you with this letter, I would much rather encourage you to work on a broader front away from the simple obstacle detector as this has proved to be virtually useless.

Yours sincerely,

L.Kay.

Lt.Cdr. John Wirtz,
Box 1265,
U.S. Naval Postgraduate School,
Monterey, California 93940,
U. S. A.

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SPECIAL PRODUCTS DIVISION
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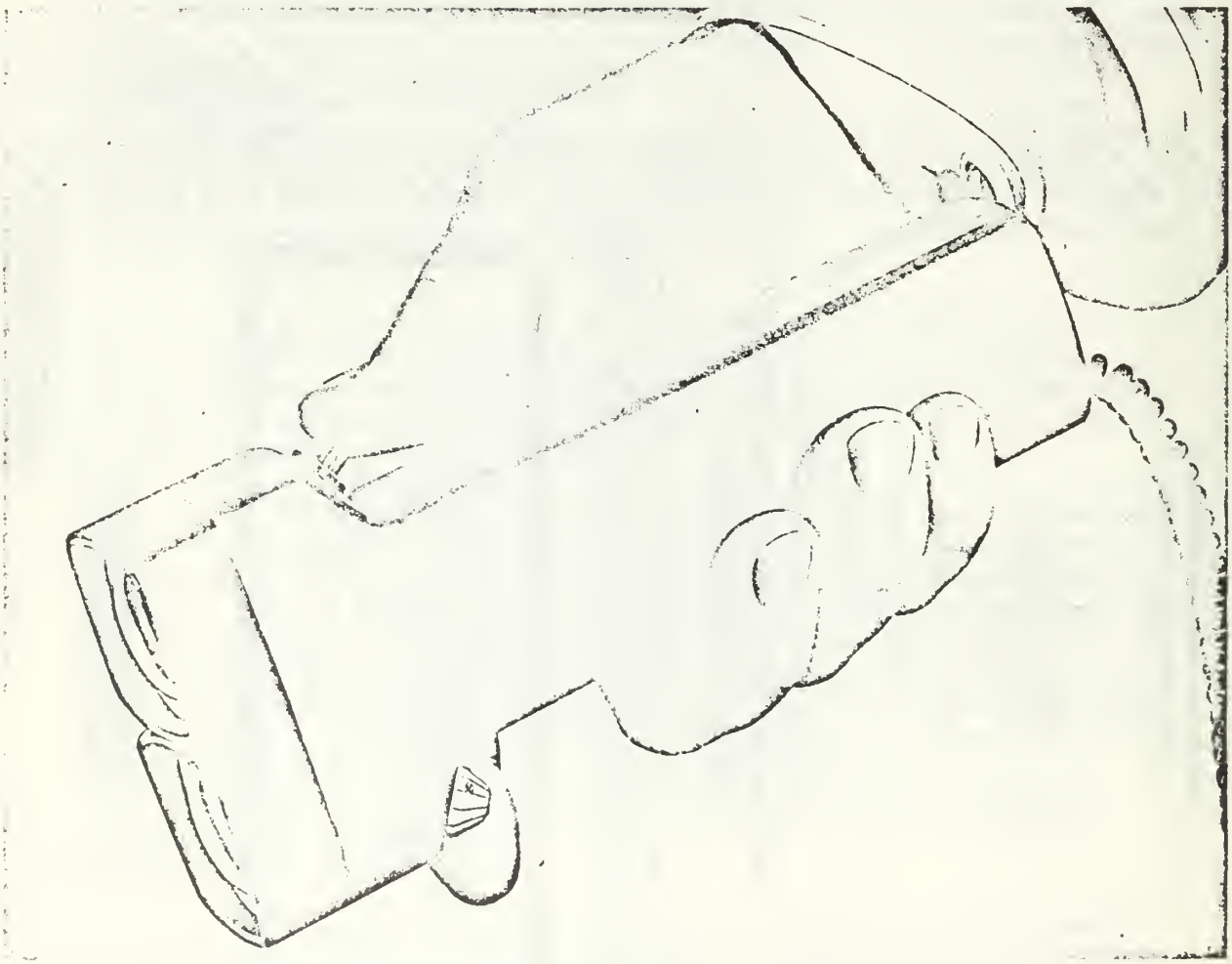
TECHNICAL BULLETIN - PROVISIONAL

ULTRA-SONIC AID FOR THE BLIND

There have been attempts from time to time in many countries to evolve some satisfactory form of guidance device to aid blind persons. The first ever to reach the production stage, following exhaustive and comprehensive tests, is the Ultra Sonic Aid for the Blind, based on a design by Dr Leslie Kay.



Telephone: ACOrn 3434. Cables: RADWAVES LONDON

The Aid consists of a transistorised transmitter-receiver, in the form of a hand-held 'torch'. It emits an ultrasonic beam of energy, whose frequency varies with time. Any energy received back by the instrument differs in frequency from that leaving it, at that instant, by an amount proportional to the time taken for the energy to travel out and be reflected back. This has the effect of producing differing signals in an earpiece, and the blind person is thus able to detect obstacles and avoid them.

The distance of the obstacles from the user can be determined by a difference in pitch - the higher the pitch, the further away the obstruction. The signals can be related to the type of surface reflecting back the varying types of note, with surfaces giving a harder type of signal.

Users who have assisted in a lengthy evaluation period have expressed the opinion that the Aid enables them to move around with less personal strain, since it eliminates the necessity for the intense concentration normally needed by a blind person to ensure mobility with safety.

The initial trials were carried out by St Dunstan's, the British organisation responsible for the welfare of the war-blinded, and, with the co-operation of the Royal National Institute for the Blind, at the Worcester College for Blind Boys.

The results of the trials have been analysed by the Applied Psychology Unit at Cambridge, and all the information which has been obtained from a lengthy programme is at the disposal of the working party committee which watches each continuing phase of activity. The committee, sponsored by Ultra Electronics Limited, also includes representatives of St Dunstan's who are members of the World Council for the Blind, the National Research Development Corporation, and the National Physical Laboratory, as well as the inventor, Dr Kay.

Complete co-operation of this kind ensures that every detail of the programme during the course of the evolution of the aid has been thoroughly discussed, so that no single item in the quest for perfection should be overlooked.

From its earliest conception, it has now been possible to produce the Aid as a single unit, with the exception of a separate battery compartment, making for ease of handling, and stowage, and to make it as inconspicuous as possible.

The programme of research and development to the production stage has been such that the Aid is offered with the assurance, backed by the leading organisations in the field, that it is in advance of any other guidance device for the blind either attempted or envisaged.

OPERATIONAL PERFORMANCE SPECIFICATION

Range:	The equipment has two ranges: (a) Short range: Zero to 7 ft max: (b) Long range: Zero to 20 ft max.
Controls:	Combined on/off switch and volume control operated by index finger. Range-change switch - spring-loaded; operated by thumb to give long range, normal position provides short range.
Detection efficiency:	The equipment will detect: (a) Objects of good reflectivity up to 20 ft away (long range). (b) A 2-inch diameter post at 10 ft. (c) A hazard such as the edge of a door at normal incidence at 3 ft, which corresponds to a 1-mm wire at this distance.
Audio transducer:	This may be used in such a way that minimum interference is caused to normal hearing.
Signal-to-noise ratio:	Noise and clicks in a free-field condition are of a low order, and such that all the conditions given under 'detection efficiency' are met.
Environment:	Temperature: The equipment will work over the range $-10^{\circ}C$ to $+40^{\circ}C$. Storage temperature varies between $-10^{\circ}C$ to $+65^{\circ}C$. The working temperature applies to the electronic unit only; normal batteries will need to be kept warm when used in low temperatures. Special low-temperature batteries are available. Waterproofing: The equipment is splashproof and capable of operating in rain and snow, and is not affected by condensation on either the electronic unit or the transducers.
Reliability:	The equipment is designed to give consistent indications, as described, for at least one year with an average use of 2 hours daily, without any servicing or maintenance other than routine changes of battery.

Maintainability:	The battery is connected to the cable from the hand-held unit by simple press-on fasteners or similar type of connector according to the type in use. The connectors are arranged so that a blind person can easily change the battery. The hand-held unit is easily dismantled and all components are accessible.
Power supply:	9V (nominal) battery. Both chargeable and expendable batteries may be used. The life of the battery will vary with its size and weight. Batteries are of a standard type available in all electrical and radio shops, and overseas.

DIMENSIONS AND WEIGHTS

Hand-held unit

Oval cross-section transducer:	major axis 3 in (7.5 cm) minor axis 1 5/8 in (4.1 cm)
Handle - oval cross-section:	tapering 2 1/4 x 1 9/16 in (5.7 x 3.9 cm) 2 x 1 5/16 in (5.2 x 3.2 cm)
Over-all length:	7 in (17.8 cm) (approx.)
Weight:	10 oz (283.5 g)
*Battery unit:	3 1/4 x 2 1/2 x 1 3/4 in (8.3 x 6.3 x 4.4 cm) 15 oz (425 g)

* Dimensions and weights of batteries depend upon duration required; the figures quoted as an example are for a battery giving 100 hours' operation.

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RD/HC

28th July, 1966.

Dear Lieutenant Commander Wirtz,

Thank you for your enquiry about ultrasonic radar for use as a blind mobility aid and I note that you are making this study in connection with your Master's Degree Thesis.

At present the two researchers who have made most progress in the field are as follows:-

Professor L. Kay, Department of Electrical Engineering,
University of Canterbury, Christchurch, New Zealand.

Lindsay Russell Esq., Apartment 5-18-C,
100, Memorial Drive, Cambridge, Massachusetts, U.S.A.

Professor Kay, who recently left this country to take up his new post in New Zealand, has worked for 6 or 7 years on his Sonic Aid. A batch of 200 aids was produced by Ultra Electronics Limited, Western Avenue, Acton, London, W.3. just over a year ago and several countries have participated in field trials. In the U.S.A., for example, Dr. L. Riley, St. Paul's Rehabilitation Centre, Boston, is currently evaluating a batch of ten of these instruments on behalf of the Veterans Administration, New York.

Brief technical details are as follows:-

A small generator driven by a 9-volt battery (shortly to be converted to a rechargeable cell) produces an FM transmission with a one octave sweep - 90kc to 45kc per pulse. In turn this permits tones of fairly pure quality to be heard in a hearing aid type earpiece as the receiver gathers the echo information from a 10° conic transmission field. The instrument has a range of 0-10 ft. on standard range and 0-25 ft. on long range.

The hand held probe with its transmit/receive transducers weighs only 10 oz. and is 7 inches long and the beam width is, of course, greatly extended by employing a co-ordinated "hand scan" along with the motion of normal walking. This is not unlike the scan technique developed in the U.S.A. for "long cane" travelling.

Mr. Russell's device gives "bleep" warning of objects about 6 feet ahead. It has been specifically designed in conjuction with M.I.T. (John Dupress) as an adjunct to the long cane just referred to above. It, therefore, gives less information but psychologists are all of the opinion that a good deal of evaluation study will still be involved to decide on the scheme that works best.

Finally I might add that Professor T.A. Benham, Haverford College, Pennsylvania, is currently developing an optical laser system built into a long cane but this is a tactile display built into the hand-grip of the cane, while Dr. James Bliss and Mr. K. Gardiner of Stanford Research Institute, have a project working on the principle of optical outlines of objects being converted again to a tactile (touch) indication.

I trust that these notes will be of assistance to you and suggest, that if a bibliography covering mobility aids for a good number of years past would help you, I believe this could be obtained from Mr. L.L. Clark, Director, International Research Information Service, American Foundation for the Blind, Inc., 15 West 16th Street, New York, N.Y. 10011.

I wish you every success with your studies and will be pleased to reply again on any specific point that you may have.

Yours sincerely,

R. Dufton, A.M.I.Mech.E.,
Director of Research.

LCDR John C. Wirtz,
Box 1265,
U.S. Naval Post Graduate School,
Monterey, California, U.S.A.

Note 1: The tones heard in the earpiece are linear with distance but are reverse from natural sound transmission, i.e. proximity is indicated by the lowesttones which increase with increasing distance and there are opposing views by scientists on this aspect.

Note 2: So far, in our own scientific evaluation based on the National Physical Laboratory, London, and using three groups of blind subjects, we have found after nearly one year the best performers travel just about as well as they did with their previous aid - a cane in most instances.

MASSA
A DIVISION OF
ELECTRONICS, INC.

REMOTE CONTROL ULTRASONIC TRANSDUCERS

MODELS
TR-7
TR-41

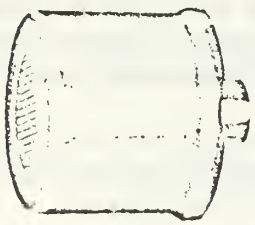
The Massa TR-7 transducer is a low-cost ultrasonic transmitter and/or receiver. Applications for the transducer are practically unlimited in fields of automation, communication, and the entertainment industry. Several hundred thousands of the Massa transducers have been used by many large television manufacturers for remote TV tuning.

Original Equipment Manufacturers now have the opportunity to incorporate into their products this remote control device that is small, efficient and low-cost, thereby eliminating any direct connection between the control device and the equipment being controlled. Control at distances up to 100 feet or more is easily obtained using the TR-7.

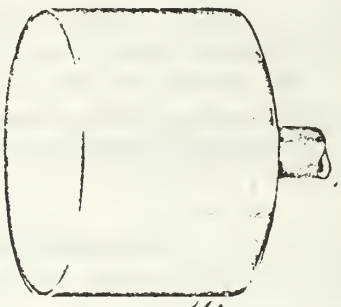
For a waterproof version of the TR-7, the TR-41 is available for use in outdoor application, e.g. garage door opening, etc.

OTHER APPLICATIONS

- BURGLAR ALARM SYSTEMS
- CARRIER FREQUENCY COMMUNICATION
- SHORT RANGE DISTANCE MEASUREMENT (SONAR, AIR) OF OBJECTS
- PROXIMITY DETECTORS



TR-7

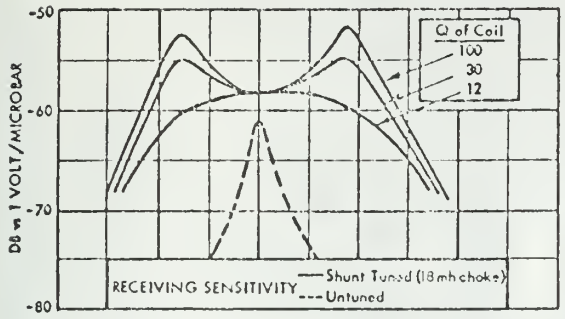


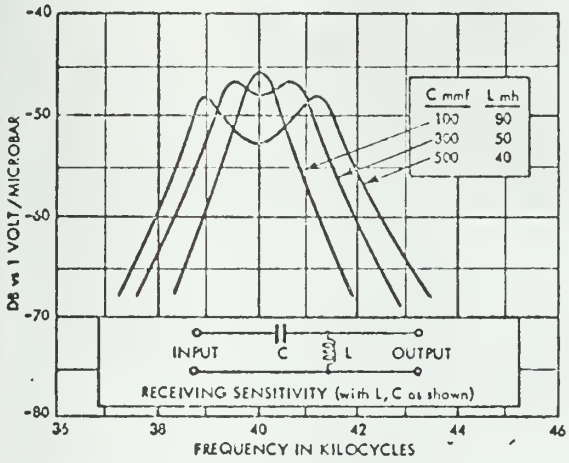
TR-41

SPECIFICATIONS

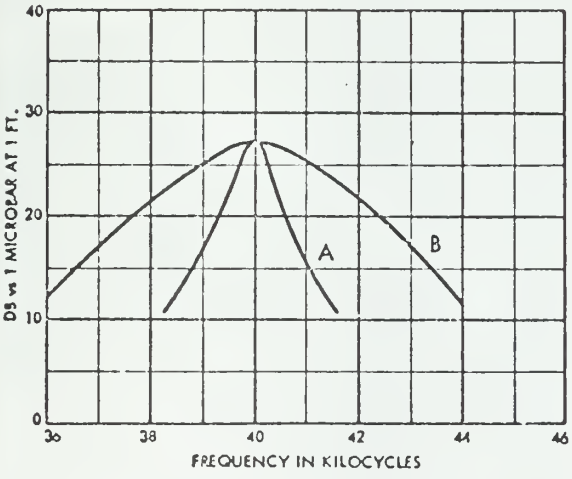
MODEL	TR-7	TR-41
PHYSICAL SIZE	1" dia. x 1" long	15/16" dia. x 1" long, and 18" length of cable
RESONANT FREQUENCY	40 kc ±1/2 kc	23 kc ± 1KC
BAND WIDTH	4 kc (with tuning choke)	2 kc (with tuning choke)
TRANSMITTING SENSITIVITY	+25 db vs 1 μbar at 1 ft. (100 mv available power)	+34 db vs 1 μbar at 1 ft. (100 mv available power)
RECEIVING SENSITIVITY	(−60 db vs 1 volt per microbar (untuned) (see curves for tuned sensitivity)	
CAPACITANCE	850 mmf	850 mmf
DIRECTIONAL CHARACTERISTICS	total beam angle 60° at 6 db down points	total beam angle 70° at 6 db down points
POWER RATING	1/2 watt steady state; 5 watts 10% duty cycle	
TEMPERATURE RATING	Less than 2% change in resonant frequency and less than 5% change in capacity over temperature range 0°F - 130°F	

PERFORMANCE CHARACTERISTICS



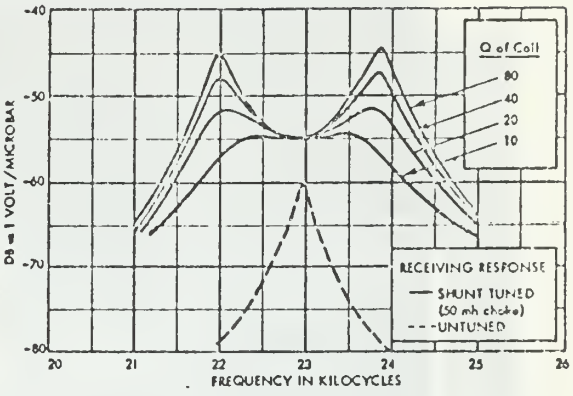


Receiving response TR-7 tronsducer.

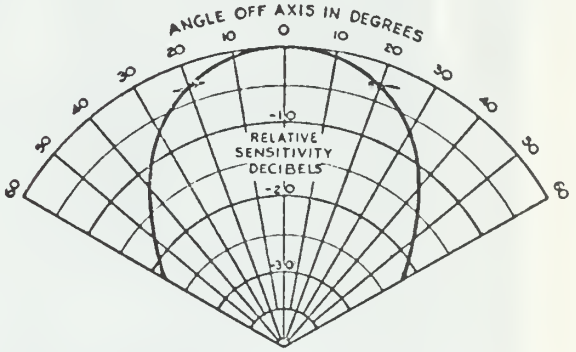


Tronsmitting response TR-7 transducer
(100 milliwatts availoble power).

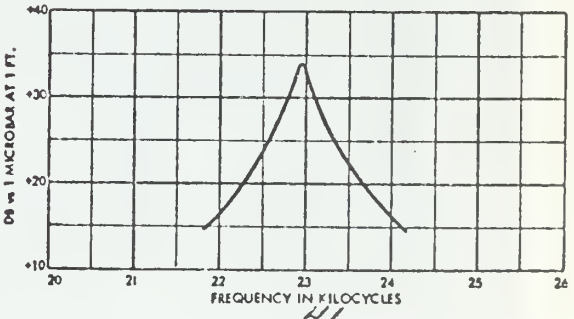
A. Untuned (4000 ohm impedance source).
B. Series tuned 18 mh (400 ohm source) or shunt tuned 18 mh (40,000 ohm source).



Frequency response TR-7 transducer



Directionol response TR-7 transducer at 40 kc.



Frequency response TR-7 transducer untuned

Transmitting response TR-7 transducer
(100 milliwotts availoble power).

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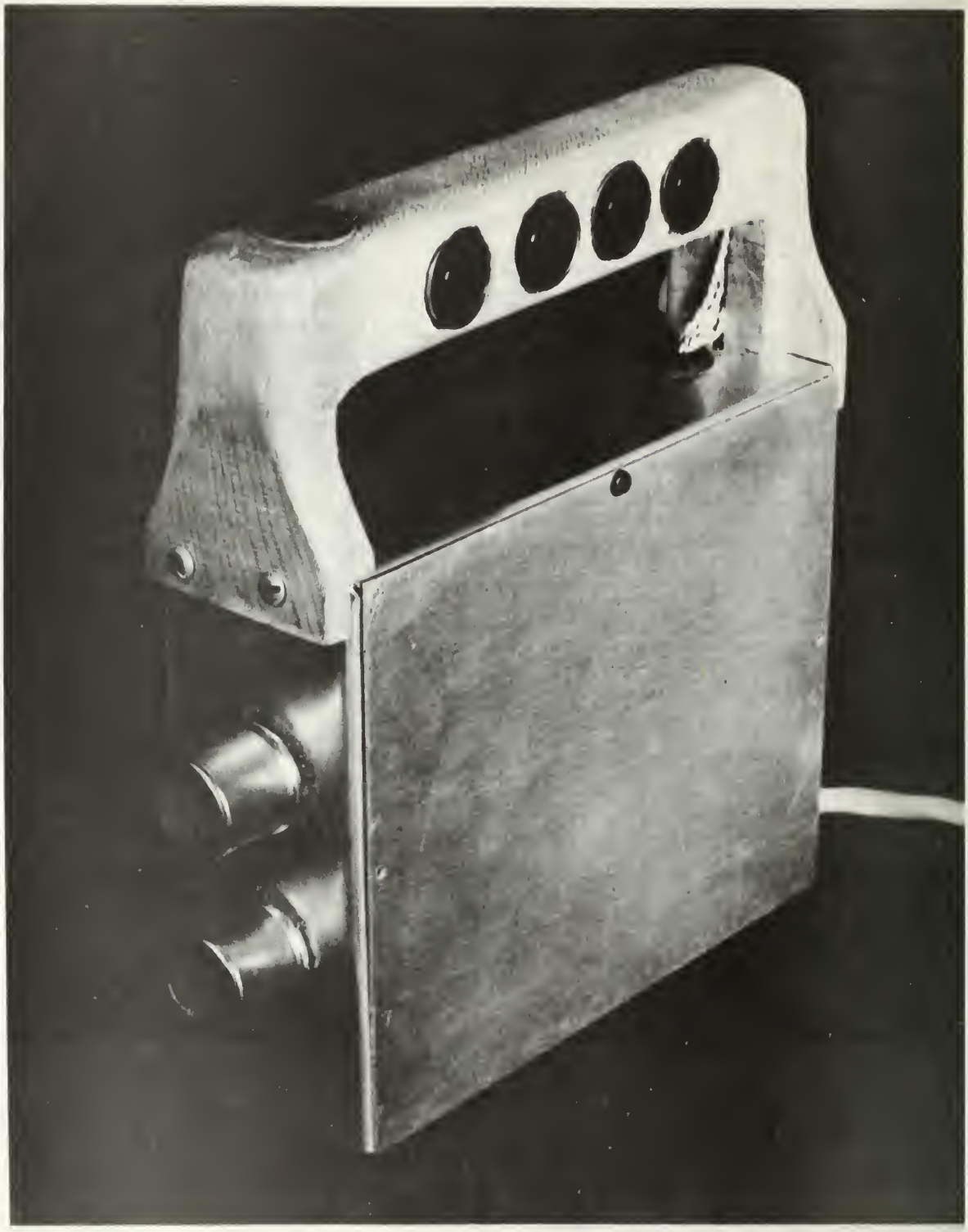
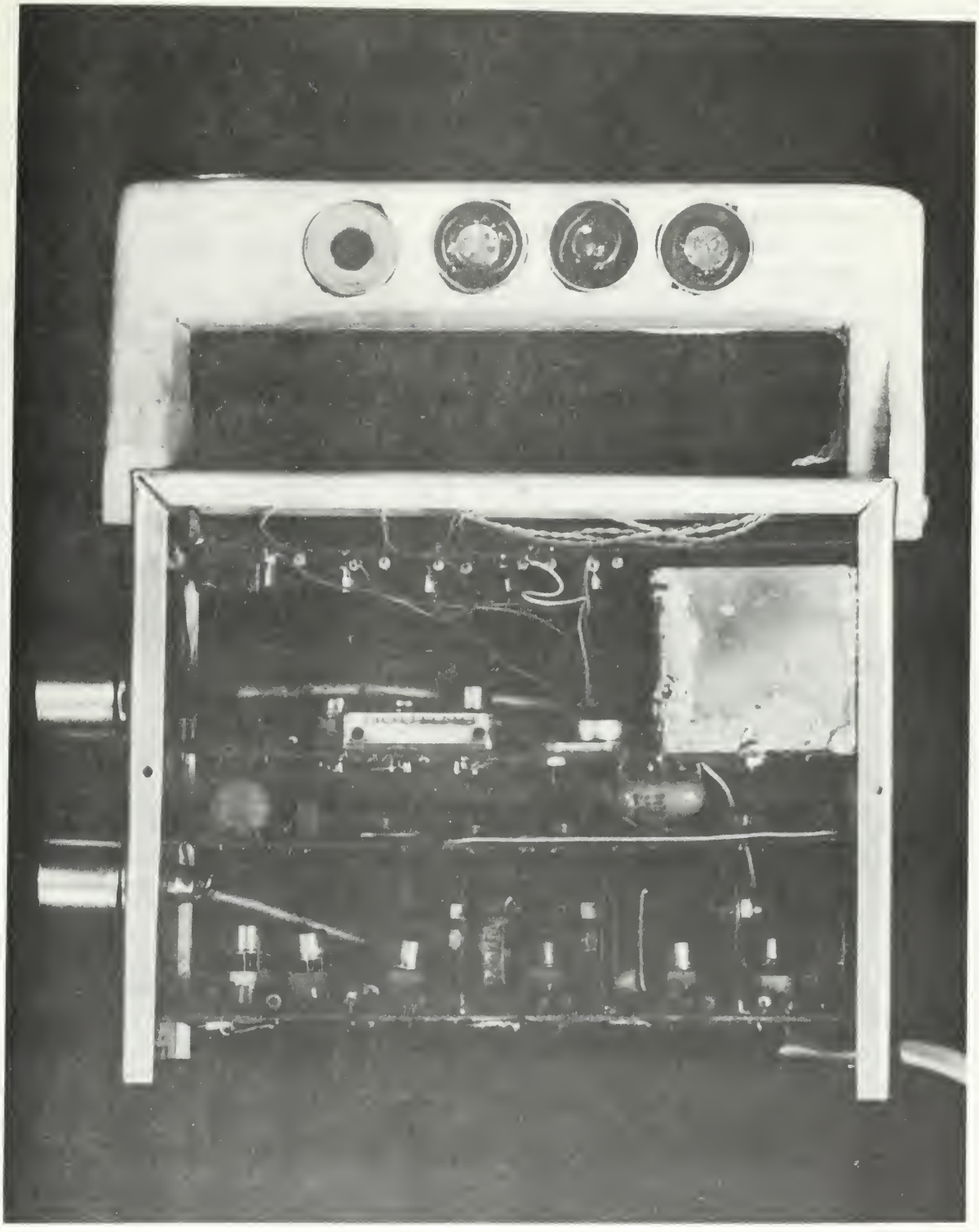
APPENDIX XVII





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3. REPORT TITLE

AN ULTRASONIC AID FOR THE BLIND

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Thesis, M.S., December 1966

5. AUTHOR(S) (Last name, first name, initial)

WIRTZ, John Carl
FREESE, David Herman Jr.

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13. ABSTRACT

In an age of rapidly advancing electronics, and subminiaturization, the possibility of providing convenient electronic aids to the physically handicapped is becoming a reality. Devices for the deaf have reached a degree of sophistication not thought possible several years ago. The blind, however, have not reaped the benefits of modern electronics technology to the degree that the deaf have. This thesis describes the work accomplished in designing and testing an ultrasonic aid for the blind. This device provides range and bearing information of nearby objects by means of tactile stimulation, and would provide a useful adjunct to the walking cane.

DD FORM 1 JAN 64 1473

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Ultrasonic Radar Aid to the Blind Blind Guidance Device						

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